In Clinical Practice

Prateush Singh *Editor*

Hand Trauma in Clinical Practice

Springer

In Clinical Practice

Taking a practical approach to clinical medicine, this series of smaller reference books is designed for the trainee physician, primary care physician, nurse practitioner and other general medical professionals to understand each topic covered. The coverage is comprehensive but concise and is designed to act as a primary reference tool for subjects across the field of medicine.

More information about this series at http://www.springer.com/series/13483

Prateush Singh
Editor

Hand Trauma in Clinical Practice

Springer

Editor
Prateush Singh
Royal Free Hospital
London
UK

ISSN 2199-6652 ISSN 2199-6660 (electronic)
In Clinical Practice
ISBN 978-3-030-10843-4 ISBN 978-3-030-10844-1 (eBook)
https://doi.org/10.1007/978-3-030-10844-1

Library of Congress Control Number: 2019934761

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

This book is a passionate celebration of many of the topics that form the foundation of plastic and hand surgery, especially those of traumatic origin, infective process and clinical relevance. It is also a unique tribute to the many authors who were involved in its production and, more importantly, to their teachers who have imparted these pearls of wisdom over generations. A further element is the abundance of colourful illustrations which decorate the pages and imagination of the reader, interweaving theory and practice in a very satisfying and appealing way.

Although the emphasis of this work is on hand trauma, it contains much that will be of interest to those outside this field or those who care to dabble occasionally in the management of such conditions or to students of medicine and surgery – indeed to anyone with a fascination with the world of trauma, injury, management and reconstruction. Although these topics represent only a small sample of what the plastic surgery universe has to offer, they amply support the importance of this field and the way in which it has evolved.

I finished reading this book one Autumn evening and felt satisfied that I had just finished an excellent and comprehensive book. The authors safely navigate the reader through the maelstrom of inevitable traumas that will befall the junior on their night on call. It is an infallible tool which will form the foundation of watertight clinical practice, providing the structural foundation for the reader to develop, learn and progress.

It is with inexpressible pleasure that I recommend this book to you.

Here ends the foreword; enjoy the journey ahead!

Professor Afshin Mosahebi, MBA, PhD, FRCS (Plast)
Professor of Plastic & Reconstructive Surgery
Royal Free Hospital & University College London
London, UK
22 October, 2018

Introduction

We use our hands every day for almost every activity. Evolutionarily refined over millennia, they are the functional and aesthetic units which shape our world. Despite this, there is a vast spectrum of injuries and infections which can have devastating effects if not managed appropriately. Hand trauma comprises a significant proportion of injuries seen internationally, and effective management remains a fundamentally important job of emergency centres, plastic surgery and orthopaedic surgery departments.

Although hand anatomy is covered comprehensively at medical school, the pathophysiology of hand trauma and its subsequent management is often less extensively taught. Junior doctors in A&E, plastic surgery and orthopaedic surgery can therefore be initially overwhelmed. We have therefore written a logical and focused book to guide the reader through the seemingly murky waters of hand trauma in a clear and stepwise manner.

London, UK — Prateush Singh

Acronyms and Abbreviations

A&E	Accident and Emergency/Emergency Department
AAGBI	Association of Anaesthetists of Great Britain and Ireland
AIN	Anterior Interosseous Nerve
AMPLE	Allergies, Medications, Past Medical History, Last Eaten, Events Leading
AP	Anterior-Posterior
APB	Abductor Pollicis Brevis
APL	Abductor Pollicis Longus
ATLS	Advanced Trauma and Life Support
CEO	Common Extensor Origin
CFO	Common Flexor Origin
CMCJ	Carpometacarpal Joint
CRPS	Complex Regional Pain Syndrome
CT	Computerised Tomography
CVA	Cerebrovascular Accident/Stroke
DIPJ	Distal Interphalangeal Joint
DOAC	Direct Oral Anticoagulant
ECG	Electrocardiogram
ECRB	Extensor Carpi Radialis Brevis
ECRL	Extensor Carpi Radialis Longus
ECU	Extensor Carpi Ulnaris
EDC	Extensor Digitorum Communis
EDM	Extensor Digiti Minimi
EIP	Extensor Indicis Propius
EPB	Extensor Pollicis Brevis
EPL	Extensor Pollicis Longus
EUA	Examination Under Anaesthesia

Ex-Fix	External Fixation
FCR	Flexor Carpi Radialis
FCU	Flexor Carpi Ulnaris
FDMA	First Dorsal Metacarpal Artery
FDP	Flexor Digitorum Profundus
FDS	Flexor Digitorum Superficialis
FOOSH	Fall onto an Outstretched Hand
FPB	Flexor Pollicis Brevis
FPL	Flexor Pollicis Longus
FTG	Full-Thickness Graft
GA	General Anaesthesia
GP	General Practitioner/Family Medicine Practitioner
Hb	Haemoglobin
HEP B	Hepatitis B
HEP C	Hepatitis C
HIV	Human Immunodeficiency Virus
I&D	Incision and Drainage
INR	International Normalised Ratio
IPJ	Interphalangeal Joint
IV	Intravenous
K-wire	Kirschner Wire
LA	Local Anaesthesia
LMWH	Low Molecular Weight Heparin
MC&S	Microbiology, Culture and Sensitivity
MCPJ	Metacarpophalangeal Joint
MRI	Magnetic Resonance Imaging
MUA	Manipulation Under Anaesthesia
NaCL	Sodium Chloride Solution/Saline
NAI	Nonaccidental Injury
NOK	Next of Kin
OP	Opponens Pollicis
ORIF	Open Reduction Internal Fixation
PCC	Prothrombin Complex Concentrate
PIN	Posterior Interosseous Nerve
PIPJ	Proximal Interphalangeal Joint
PONV	Postoperative Nausea and Vomiting
POP	Plaster of Paris

POSI	Position of Safe Immobilisation
RDA	Radial Digital Artery
RDN	Radial Digital Nerve
SBRN	Superficial Branch of Radial Nerve
STSG	Split-Thickness Skin Graft
TBSA	Total Body Surface Area
TIA	Transient Ischaemic Attack
UDA	Ulnar Digital Artery
UDN	Ulnar Digital Nerve
UFH	Unfractionated Heparin
CHA2DS2-VASc	Congestive Heart Failure, Hypertension, Age, Diabetes Mellitus, Stroke/TIA/VTE, Vascular Disease, Age, Sex Category
UGRA	Ultrasound-Guided Regional Anaesthesia
VTE	Venous Thromboembolism

Contents

Contributors

Pallavi Arya Department of General Surgery, Royal London Hospital, London, UK

Christopher Deutsch Department of Plastic Surgery, Royal Free Hospital, London, UK

Muholan Kanapathy Department of Plastic Surgery, Royal Free Hospital, London, UK

Norbert Kang Department of Plastic Surgery, Royal Free Hospital, London, UK

Wojciech Konczalik Department of Plastic Surgery, Royal Free Hospital, London, UK

Kapila Mendis Department of Plastic Surgery, Royal Free Hospital, London, UK

Joanna Mennie Department of Plastic Surgery, Royal Free Hospital, London, UK

Dominika Michno Department of Plastic Surgery, Royal Free Hospital, London, UK

Naghmeh Naderi Department of Plastic Surgery, Royal Free Hospital, London, UK

Raj Shah Department of Regional Anaesthesia, Royal Free Hospital, London, UK

Esha Singh Department of Plastic Surgery, Royal Free Hospital, London, UK

Rakesh Singh General Practitioner, All Saints Surgery, Burton, UK

Ravina Tanna Department of Plastic Surgery, Royal Free Hospital, London, UK

Amitabh Thacoor Department of Plastic Surgery, Royal Free Hospital, London, UK

Alexander Trevatt Department of Plastic Surgery, Royal Free Hospital, London, UK

Roshan Vijayan Department of Plastic Surgery, Royal Free Hospital, London, UK

Zak Vinnicombe Department of Plastic Surgery, Royal Free Hospital, London, UK

Chapter 1
Hand Anatomy

Esha Singh and Naghmeh Naderi

A thorough awareness of hand and upper limb anatomy is vital to understanding injuries to these regions, planning subsequent management, and anticipating complications. We will review anatomy here systematically;

- Nailbed
- Muscles & Tendons
- Pulleys & Volar plate
- Arteries & Vinculae
- Nerves
- Bones

1.1 Nailbed

The nailbed is a common region of injury throughout all ages. It is comprised of a nail bed made proximally of germinal matrix and distally of sterile matrix, covered by a nail plate (Fig. 1.1). Crush injuries of the distal phalanx involving the nailbed are common. Initial assessment should examine for neurovascular viability of the surrounding soft tissue, and an x-ray radiograph to highlight underlying fractures of the distal phalanx.

E. Singh (✉) · N. Naderi
Department of Plastic Surgery, Royal Free Hospital, London, UK

P. Singh (ed.), *Hand Trauma in Clinical Practice*, In Clinical Practice, https://doi.org/10.1007/978-3-030-10844-1_1

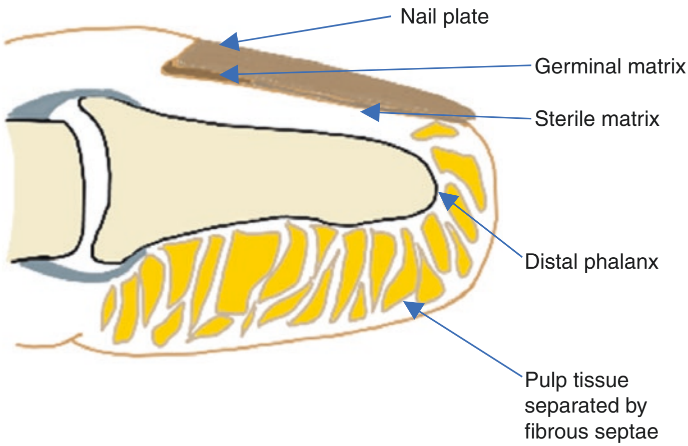

FIGURE 1.1 Nailbed anatomy

Underlying distal phalanx fractures may be managed differently depending on their location. Distal third crush fractures (Fig. 1.2) are termed 'Tuft' fractures and can be managed by surgically reconstituting the surrounding soft tissue which then acts as a splint for bone healing. Oral antibiotics are also given as such injuries constitute 'open fractures' and antibiotics and nailbed repair reduce the risk of osteomyelitis. Fractures of the proximal third of the distal phalanx are likely to require surgical bone fixation to prevent slipping of the fracture given the insertion and pull of FDP or EDC. Fractures of the middle third of the distal phalanx must be assessed individually for stability and can be treated conservatively or with surgical bony fixation.

In children, nailbed injuries with underlying extra-articular distal phalanx fractures involving the physis are termed 'Seymour fractures' and can look like mallet finger abnormalities in adults. In Seymour fractures, this occurs as the EDC inserts in to the epiphysis but the FDP inserts in to the metaphysis, thereby pulling the distal phalanx in to a flexed position. Surgical fixation is required to remove any tissue trapped in the growth plate to prevent non-union, growth arrest and a permanent fixed flexion deformity. If the

FIGURE 1.2 Tuft fracture of distal phalanx

fracture remains unstable, an axial Kirschner (K-wire) wire may be required for added support.

Nailbed repair involves removal of the nail plate and closure of the underlying nailbed laceration, usually with a small-sized, rapidly absorbable suture like 6-0 Vicryl Rapide. A subungal haematoma >40% surface area of the nailbed warrants this repair. Where the laceration is more proximal, longitudinal proximal incisions in to the eponychium may be required to expose the laceration (raising eponychial flaps) and repair it primarily. The primary reason for repair is to reduce the risk of osteomyelitis as nail bed lacerations can allow passage of bacteria in to the underlying fracture.

The nail plate grows from the germinal matrix, so damage here may result in abnormal or absent subsequent nail plate growth. Where terminalisations are needed, it is imperative

that any residual germinal matrix is excised and ablated to prevent growth of sharp nail spicules.

1.2 Muscles and Tendons

Extrinsic muscles and tendons of the forearm are divided into flexor (anterior) and extensor (posterior) compartments.

Intrinsic muscles are found within the hand itself and are critical for further dexterity and finer movements.

1.2.1 The Flexor (Anterior) Compartment (Table 1.1)

Within the flexor compartment of the forearm, muscles are divided in to superficial (Fig. 1.3), middle (Fig. 1.4) and deep (Fig. 1.5) layers.

Key movements: wrist and finger flexion, and forearm pronation.

Key nerves: median and ulnar nerves.

The superficial compartment muscles are flexor carpi ulnaris (FCU), palmaris longus (absent in 15% of the popula-

TABLE 1.1 Extrinsic flexor muscles of the hand

Muscle	Origin	Insertion	Action	Nerve
Superficial Compartment (4 muscles)				
FCU	CFO	Pisiform	Flexion & ulnar deviation wrist	ulnar
Palmaris longus	CFO	Flexor retinaculum + palmar fascia	Flexion wrist	median
FCR	CFO	Base second, third metacarpals	Flexion & radial deviation wrist	median

Table 1.1 (continued)

Muscle	Origin	Insertion	Action	Nerve
Pronator teres	CFO & coronoid process ulna	Mid shaft radius	Pronation forearm	median
Middle Compartment (1 muscle)				
FDS	CFO & radius	Four tendons travel through carpel tunnel; insert to middle phalanx of index, middle, ring and little fingers.	Flexion of MCPJ and PIPJ of 4 fingers & wrist	median
Deep Compartment (3 muscles)				
FDP	Ulna & interosseous membrane	Four tendons travel through carpal tunnel; insert to distal phalanx of index, middle, ring and little fingers via Camper's chiasm (splitting of FDS tendon at middle phalanx)	Flexion of DIPJ of 4 fingers & PIPJ & MCPJ & wrist	Ulnar half by ulnar nerve, radial half by AIN.
FPL	Anterior radius & interosseous membrane	Distal phalanx thumb	Flexion IPJ & MCPJ thumb	AIN
Pronator quadratus	Anterior ulna	Anterior radius	Pronation forearm	AIN

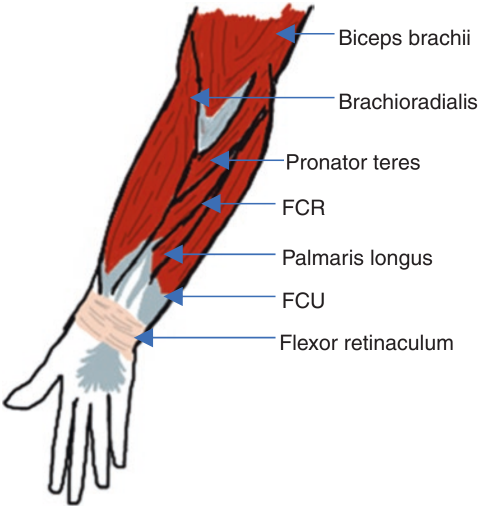

FIGURE 1.3 Superficial flexor compartment

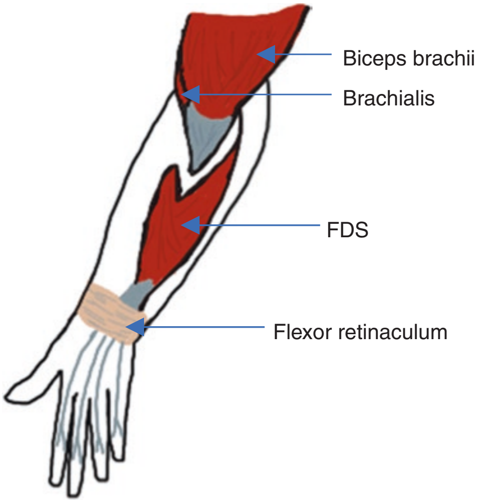

FIGURE 1.4 Middle flexor compartment

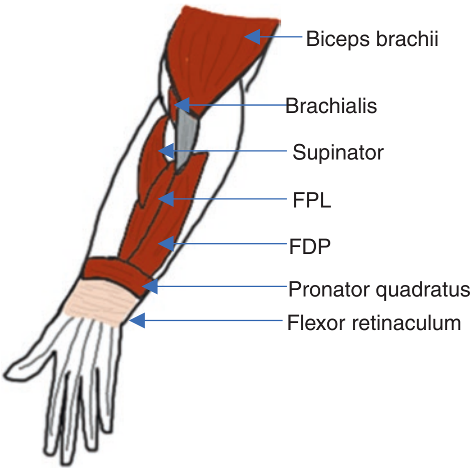

FIGURE 1.5 Deep flexor compartment

tion and a common choice for tendon graft donor in staged flexor tendon reconstruction as harvesting leaves little functional deficit), flexor carpi radialis (FCR) and pronator teres. They originate from the common flexor origin (CFO) at the medial epicondyle of the humerus. The median nerve can be found underneath the palmaris longus at the wrist.

The middle compartment comprises the flexor digitorum superficialis (FDS). The median nerve and ulnar artery pass between its two heads.

The deep compartment muscles are flexor digitorum profundus (FDP), flexor pollicis longus (FPL) and pronator quadratus. Innervation is by the anterior interosseous nerve (AIN) off the median nerve, and the ulnar nerve.

1.2.2 *Flexor Tendon Zones*

Injuries to the anterior, volar, aspect of the hand and forearm are described by five zones (Fig. 1.6).

- Zone I: Distal to FDS insertion

- Zone II: A1 pulley to FDS insertion
- Zone III: A1 pulley to carpal tunnel
- Zone IV: Carpal tunnel
- Zone V: Proximal to carpal tunnel

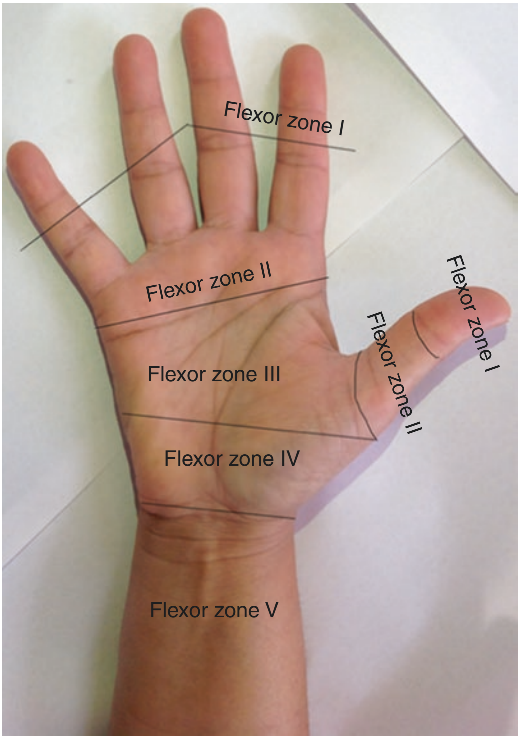

FIGURE 1.6 Flexor zones

1.2.3 Flexor Tendon Sheath

The flexor sheath is a fibrous tube containing the tendon from the A1 to the A5 pulley allowing for smooth glide (Fig. 1.7).

1.2.4 Pulleys

Pulleys are either cruciate and annular (Fig. 1.8). Annular pulleys function to prevent bowstringing. A2 and A4 pulleys arise from the periosteum of the proximal and middle phalanges respectively and are most important in preventing bowstringing. Care must be taken not to vent both intraoperatively and to repair or reconstruct vented pulleys wherever possible. A1, A3 and A5 pulleys arise from the volar

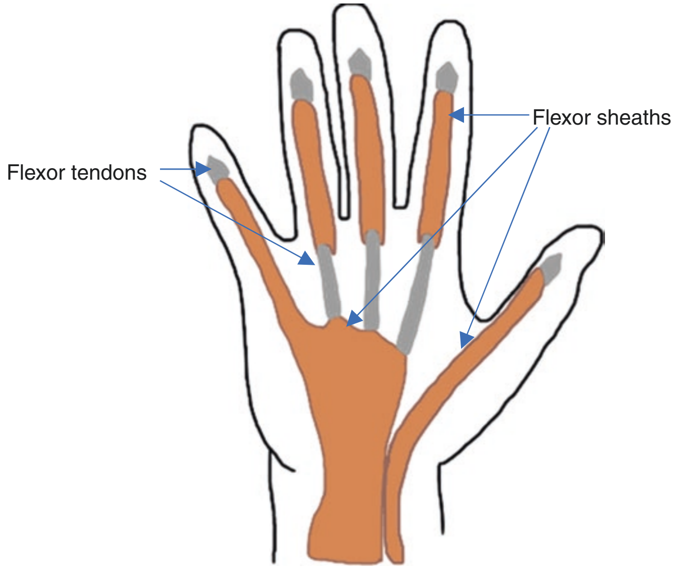

FIGURE 1.7 Flexor tendon sheaths

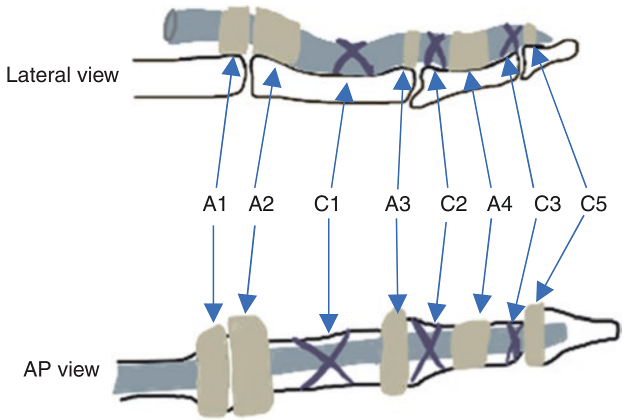

Figure 1.8 Flexor tendon pulleys

plates of the MCPJs, PIPJs and DIPJs. The A1 pulley is commonly involved in trigger finger, by catching the inflamed flexor tendon and preventing active extension of the finger.

Cruciate pulleys function to prevent sheath collapse and expansion during movement, and facilitate approximation of annular pulleys during flexion to further minimize bowstringing.

The thumb has an oblique pulley originating from the proximal phalanx and running between A1 and A2 pulleys, which also prevents bowstringing of FPL. Bowstringing will occur if the oblique and A1 pulley in the thumb are cut.

1.2.5 Volar Plate

The volar plate is a collection of soft tissue on the volar aspect of the MCPJs and IPJs (Fig. 1.9). It functions to stabilise joint capsules, prevent hyperextension and separate the overlying flexor tendons from the underlying bone and joints to facilitate smooth glide and reduce friction. Hyperextension injuries can damage the volar plate and isolated volar plate injuries or those with a small accompanying avulsion fracture can be managed conservatively with a Zimmer splint and hand therapy.

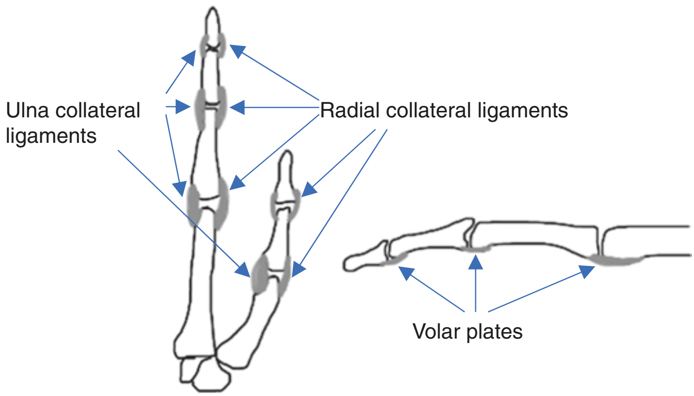

FIGURE 1.9 Volar plates and collateral ligaments

1.2.6 The Extensor (Posterior) Compartment

In the extensor compartment of the forearm, the muscles are divided in to superficial (Fig. 1.10) and deep (Fig. 1.11). They enter the dorsal wrist in six synovium-lined compartments (Table 1.2).

Key movements: wrist and finger extension.

Key nerves: radial and posterior interosseous nerve (PIN).

The superficial compartment contains seven muscles, four of which originate from the common extensor origin (CEO) at the lateral epicondyle of the humerus; extensor carpi radialis brevis (ECRB), extensor digitorum communis (EDC), extensor carpi ulnaris (ECU), extensor digiti minimi (EDM). Other superficial muscles arising from elsewhere include brachioradialis, extensor carpi radialis longus (ECRL), and anconeus.

The deep compartment contains five muscles; supinator, abductor pollicis longus (APL), extensor pollicis longus (EPL), extensor pollicis brevis (EPB), extensor indicis proprius (EIP).

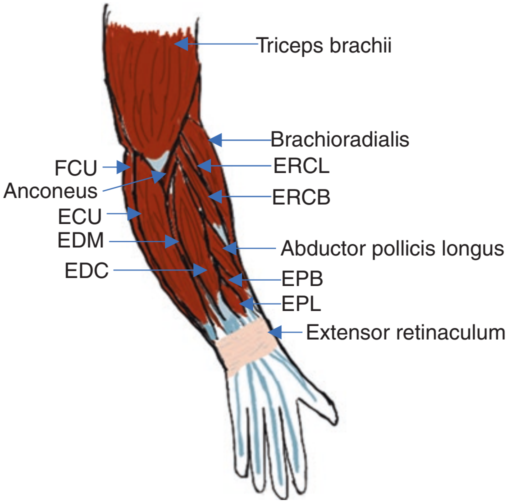

FIGURE 1.10 Superficial extensor compartment

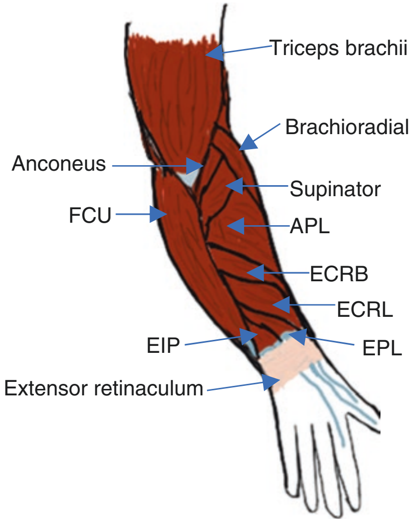

FIGURE 1.11 Deep extensor compartment

TABLE 1.2 Extrinsic extensor muscles of the hand

Compartment	Muscle	Origin	Insertion	Action	Nerve
First	APL	Interosseous membrane & posterior surface ulna and radius	Base first metacarpal	Thumb abduction	PIN
	EPB	Interosseous membrane & posterior surface radius	Base proximal phalanx thumb	Extension thumb MCPJ & CMCJ.	PIN
Second	ECRL	Supracondylar ridge humerus	Base second metacarpal	Wrist extension & radial deviation	Radial
	ECRB	CEO	Base third metacarpal	Wrist extension & radial deviation	Radial
Third	EPL	Interosseous membrane & posterior surface ulna	Base distal phalanx thumb	Extension thumb IPJ, MCPJ, CMCJ.	PIN
Fourth	EDC	CEO	Extensor hood of each finger, proximal and distal phalanx	Extension MCPJ, PIPJ, DIPJ of fingers	Deep branch radial
	EIP	Interosseous membrane & posterior surface ulna	Extensor hood index finger	Extension index finger	PIN
Fifth	EDM	EDC	Extensor hood little finger	Extension little finger & wrist	Deep branch radial
Sixth	ECU	CEO	Base fifth metacarpal	Ulnar deviation & wrist extension	Deep branch radial

1.2.7 Extensor Apparatus (Fig. 1.12)

The EDC tendons insert into connective tissue at the MCPJs called the extensor apparatus and continue distally as the central slip which inserts into the base of the middle phalanx and contributes to extension of the PIP joint. At the point of separation of the central slip, two lateral slips arise from EDC to insert into the base of the distal phalanx as the terminal tendon and allow extension of the DIP joint. There are sagittal bands that originate from the volar plate and add stability to the extensor tendon over the MCPJ.

1.2.8 Extensor Zones

Injuries to the posterior aspect of the hand and forearm are described by eight zones with odd numbers located at joints (Fig. 1.13).

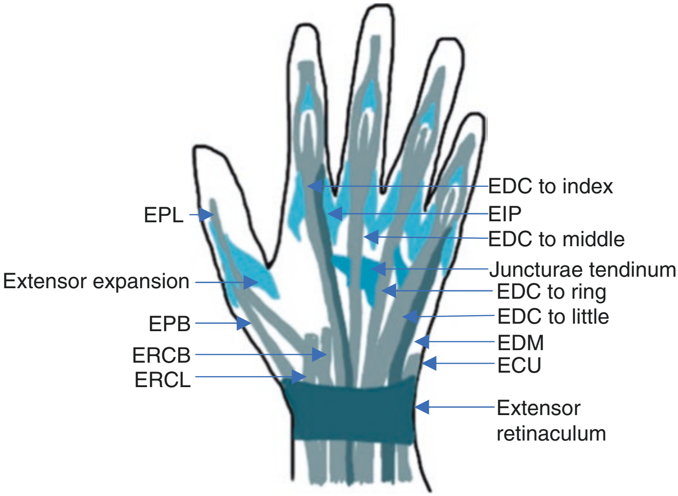

Figure 1.12 Extensor tendons in the hand

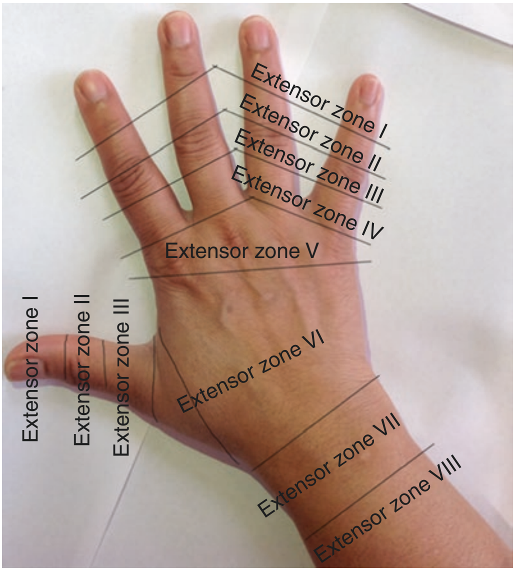

FIGURE 1.13 Extensor zones

1.2.9 *Intrinsic Muscles of the Hand*

These muscles are located within the hand itself and allow for fine motor actions (Table 1.3).

These muscles include adductor pollicis, palmaris brevis, palmar and dorsal interoseei, lumbricals, thenar and hypothenar muscles.

Key nerves: ulnar and median nerves.

Lumbricals link extensor and flexor tendons and their action results in flexion of the MCPJs and extension of the IPJs (Fig. 1.14). Denervation of the ulnar two lumbricals via the deep branch of the ulnar nerve results in ulnar claw hand; denervation of the radial two lumbricals via the deep motor branch of the median nerve results in hand of Benediction.

Dorsal interossei cause finger abduction (Fig. 1.15) and palmar interossei cause finger adduction (Fig. 1.16).

Table 1.3 Intrinsic muscles of the hand

Muscle	Origin	Insertion	Action	Innervation
Lumbricals	From FDP tendons	Extensor hoods	Flex MCPJ, extension IPJs	Lateral 2 – median Medial 2 – ulnar
Interossei (8 muscles)				
3 Palmar interossei	Sides metacarpals	Extensor hood & proximal phalanx of 4 fingers	Adduction MCPJ fingers	ulnar
4 Dorsal interossei	Sides metacarpals	Extensor hood & proximal phalanx of 4 fingers	Abduction MCPJ fingers	ulnar
Thumb (4 muscles)				
Thenar: Abductor pollicis brevis (APB)	Scaphoid, trapezium, flexor retinaculum	Proximal phalanx thumb	Abduction CMCJ thumb	median
Thenar: Flexor pollicis brevis (FPB)	Trapezium, flexor retinaculum	Proximal phalanx thumb	Flexion MCPJ thumb	median

Thenar: Opponens pollicis (OP)	Trapezium, flexor retinaculum	First metacarpal	Medial rotation at CMCJ & flexion IPJ: opposition	median
Adductor pollicis (Fig. 1.17)	Base second & third metacarpals & capitate	Base thumb proximal phalanx	Adduction thumb at MCPJ	ulnar
3 hypothenar muscles				
Abductor digiti minimi (most superficial)	Pisiform & FCU tendon	Base proximal phalanx little finger	Little finger abduction at MCPJ	ulnar
Flexor digiti minimi (lateral to ADM)	Hook of hamate & flexor retinaculum	Base proximal phalanx little finger	Flexion MCPJ little finger	ulnar
Opponens digiti minimi (deepest muscle)	Hook of hamate and flexor retinaculum	Fifth metacarpal	Rotation of fifth metacarpal, flexion at fourth and fifth MCPJ	ulnar

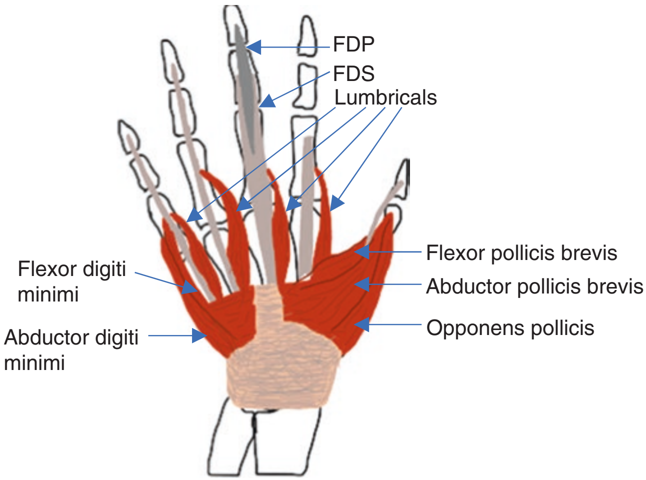

FIGURE 1.14 Lumbricals, thenar and hypothenar muscles

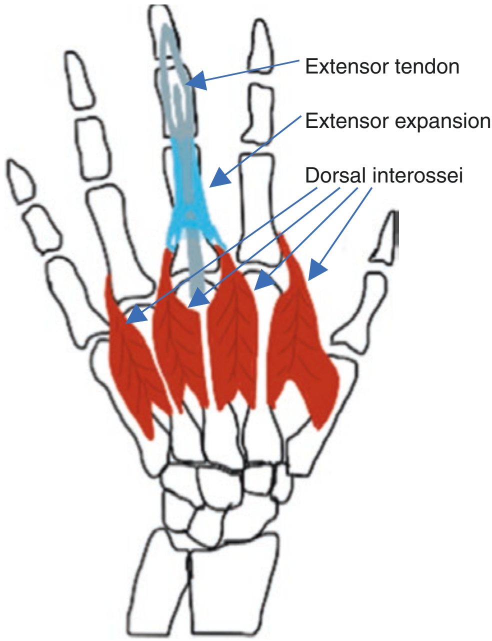

FIGURE 1.15 Dorsal interossei

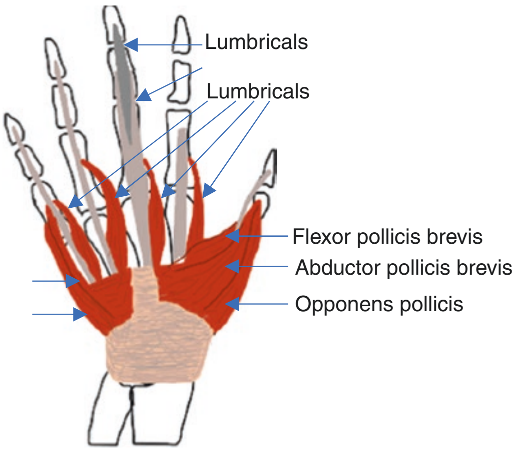

FIGURE 1.16 Palmar interossei

1.3 Arteries (Fig. 1.17)

The radial artery arises from the brachial artery and courses between brachioradialis and FCR, dividing into a dorsal and volar branch. The dorsal branch traverses the dorsal aspect of the hand over the anatomical snuffbox before passing volarly between the two heads of adductor pollicis to becomes the deep palmar arch. The smaller volar branch contributes to the superficial palmar arch of the ulnar artery.

The ulnar artery runs under FCU and can be identified radially to the ulnar nerve at the wrist. It enters the hand through Guyon's canal with the ulnar nerve and divides in to two branches. The larger of which forms the superficial palmar arch, and the smaller of which contributes to the deep palmar arch of the radial artery.

The superficial palmar arch lies deep the palmar fascia, and gives off the common digital arteries. These arteries are located more volar than the common digital nerves in the palm. They bifurcate at the level of the MCPJs into radial and ulnar proper digital arteries, which then become dorsal to the proper digital nerves in the finger neurovascular

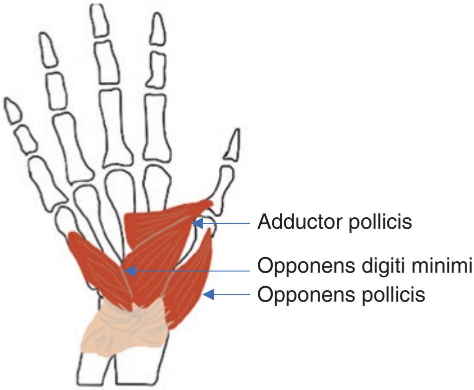

FIGURE 1.17 Adductor Pollicis and Opponens muscles

bundles. As digital arteries continue distally they reduce in vessel diameter, thereby making re-anastomoses after amputations or injuries more difficult technically and less likely to function.

The deep palmar arch lies deep to the flexor tendons and gives off the palmar metacarpal arteries, the princeps pollicis artery to the thumb and the radial digital artery to the index finger. The thumb also receives a powerful dorsal supply from the radial artery.

1.3.1 Vinculae

Vinculae are the conduits by which vascular supply enters a tendon within a synovial sheath (Fig. 1.18). There are two for each flexor tendon, one long and one short. The two vincula brevia in each finger connect the FDP to the middle phalanx, and FDS to the proximal phalanx; and the two vincula longa in each finger connect the FDP to the FDS, and the FDS to the proximal phalanx (Fig. 1.19).

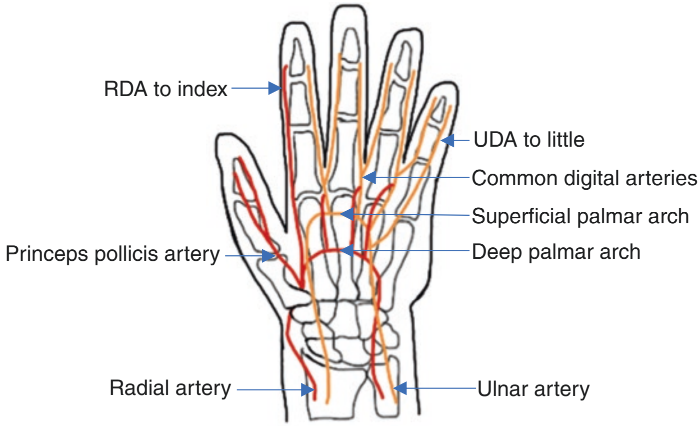

FIGURE 1.18 Arteries and palmar arterial arches in the hand

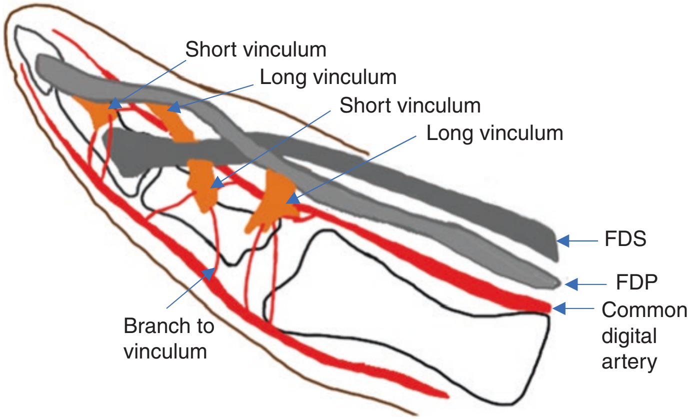

FIGURE 1.19 Vinculae

1.4 Nerves

1.4.1 Median Nerve

The median nerve originates from the union of the medial and lateral cords of the brachial plexus and has contributions from C5-T1 nerve roots. It enters the arm through the axilla and travels alongside the brachial artery, on top of brachialis and underneath biceps brachii. In the arm it initially lies lateral to the brachial artery, then traverses anterior to it just proximal to the cubital fossa, then continues to lie medial to the artery.

As it continues through the forearm, it passes between the two heads of pronator teres, then between the FDS lying above and the FDP below. Just proximal to the flexor retinaculum it passes between the FDS lying medially and FCR lying laterally and passes through the carpal tunnel at the wrist along with tendons from FDS, FDP and FPL.

Once in the hand, the median nerve gives off some branches;

The recurrent motor branch which supplies the three thenar muscles.

The proper palmar digital branch which supplies three digital nervesXE to thumb and radial 2 and a half fingers.

1.4.2 Ulnar Nerve

The ulnar nerve originates from the medial cord of the brachial plexus and has contributions from C8-T1 nerve roots. It enters the arm through the axilla and travels medial to the brachial artery in the arm. At the insertion of coracobrachialis, it pierces the intermuscular septum to continue its descent in the posterior compartment of the arm. Here it passes posterior to the medial epicondyle of the elbow where it can be easily palpated.

The ulnar nerve then enters the anterior compartment of the forearm between the two heads of FCU, and passes between the FDS lying laterally and the FDP lying medially. At the wrist, it passes over the flexor retinaculum to enter the hand via Guyon's canal, along with the ulnar artery.

Once in the hand, the ulnar nerve gives off some branches;

The superficial branch which supplies palmaris brevis and provides digital branches to the medial one and a half digits.

The deep branch which supplies the hypothenar muscles, ulnar two lumbricals., all the interossei of the hand, and adductor pollicis.

1.4.3 Radial Nerve

The radial nerve originates from the posterior cord of the brachial plexus and has contributions from C5-T1 nerve roots. It enters the arm in the axilla and descends between the medial and lateral heads of triceps brachii alongside the profundal brachii artery. The nerve then pierces the intermuscular septum to enter the anterior compartment of the arm and descends over the lateral epicondyle of the humerus. The radial nerve gives off the posterior cutaneous nerve of the arm and forearm providing sensation.

The radial nerve then divides in to its superficial and deep branches. The superficial branch of the radial nerve (SBRN) passes under brachioradialis to supply sensation to the dorsal aspect of the hand, thumb and radial two and a half fingers (not including the nail beds which are supplied by the median nerve).

The deep branch of the radial nerve is also termed the 'posterior interosseous nerve/ PIN' and innervates numerous structures in the forearm.

1.5 Bones

Bones form the structural integrity of the hand (Fig. 1.18). They are divided in to

- Carpal bones (proximal and distal rows)
- Metacarpal bones
- Phalanges

The carpal bones are divided in to a proximal row comprised of scaphoid, lunate, triquetral, and pisiform bones, and a distal row comprised of trapezium, trapezoid, capitate and hamate (Fig. 1.20).

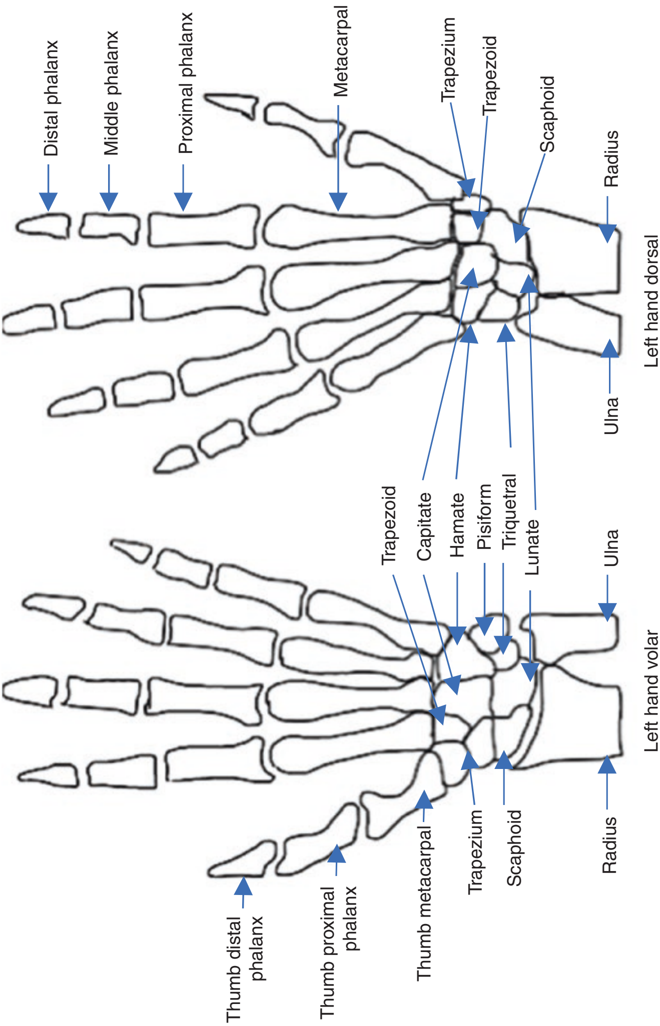

FIGURE 1.20 Bones of the hand

Chapter 2
History and Examination

Pallavi Arya, Muholan Kanapathy, and Kapila Mendis

Performing a detailed and streamlined history and examination it's the only means to ascertain the true nature of an injury and which structures are likely to be damaged. They will guide immediate management, subsequent further investigations and imaging, and definitive treatment.

2.1 History of Events

This provides clues to the nature of the underlying injury; the extent and region of damage, which key structures are likely to be damaged, and what is repairable given the time frame.

Mechanism of injury: for each injury it is necessary to elucidate time, causative mechanism, blunt/sharp trauma, location, immediate management already performed, possibility of foreign body in wound, open or closed nature of wound, hand position at time of injury, high/low energy impact, any other injuries;

P. Arya (✉)
Department of General Surgery, Royal London Hospital, London, UK
e-mail: pallavihumaarya@doctors.org.uk

M. Kanapathy · K. Mendis
Department of Plastic Surgery, Royal Free Hospital, London, UK

P. Singh (ed.), *Hand Trauma in Clinical Practice*, In Clinical Practice, https://doi.org/10.1007/978-3-030-10844-1_2

- Lacerations
- Degloving injuries: assess for viability of degloved tissue and underlying structures
- Crush: check duration of crush, time since injury and height object fell
- Avulsion/Amputation: check they have the distal tissue and viability of amputated segment
- Bites: Human/animal (vaccinated or not, and tetanus status)
- Punch: what/who was punched and possibility of foreign body in the wound
- Penetrating injuries: Multiple structures can be damaged in multiplanar fashion depending on length, depth and number of penetrations and the shape of the object; always check for a possible foreign body
- Blast injuries: deep seated foreign bodies in the wound and fractures
- Burn injuries: TBSA%, burn agent, contact period, location- consider early referral to burns units or centres.
- Fall (FOOSH = fall on out stretched hand)
- Other: previous trauma/gardening/DIY/foreign travel/

Other factors in the history:

- It is critical to ascertain if co-existing problems caused or contributed to the injury- these problems may take precedence to the hand trauma issue. For example, if the injury was caused by a loss of consciousness/seizure/acute intracranial event, this needs to be addressed as a priority. At all times an ATLS algorithm should be used to address lifesaving, then limb saving injuries and a primary and secondary survey approach taken.
- Chronology of events: Time of injury, presentation to referring hospital, time delay until now, reason for delay. A delay is particularly concerning for revascularized tissue (concern regarding viability) & paediatric injuries (concern regarding NAI).

- Environment: assess the likelihood of wound contamination or chemical damage
- Management to date: what treatment has been performed already, in particular debridement of wound edges in bites, irrigation, tetanus, antibiotics, analgesia, imaging.
- What symptoms have they experienced; including pain, reduced movement or sensation, changes in swelling, colour, temperature, deformity, discharge. Be sure to take microbiology samples where appropriate.
- Any improving symptoms since the injury; improving numbness in the hand or a digit following release of compression dressing can be due to pressure effect rather than true nerve injury. It is important to differentiate a neuropraxia from a neurotmesis as management is different.
- Any worsening symptoms since the injury; a rapid increase in pain, with increasing numbness and loss of function may indicate compartment syndrome, more common in crush or high velocity injection injuries, and requires urgent decompression.
- A full AMPLE history including allergies, medications, past medical problems, last ate or drank and events leading up to the injury, is required.

2.1.1 Non-accidental Injury (NAI)

One must always have a low threshold of suspecting NAI in all age groups and genders, particularly children. This can be suspected through inconsistencies in the history, delays to presentation, other injuries on the child, guardians who accompany the child, multiple attendances and unusual behavior from the child or guardians. If there is concern, this should be immediately escalated to the A&E lead for child protection, or the paediatric on-call team and the child may need to be kept in hospital for safeguarding reasons.

2.1.2 Patient Factors

These factors will influence subsequent management and allow for holistic patient care, along with the potential long-term sequelae or complications.

Definitive factors

- Age/Sex/Hand Dominance

Medical history

- Co-morbidities: Arthritis with already deformed fingers prior to trauma, and rheumatoid arthritis may raise concerns regarding c-spine stability during intubation
- Previous injuries to the same anatomical region can distort anatomy
- Previous surgeries particularly with regard to blood supply and connective tissue
- Previous anaesthesia: if there are were any complications, and when the last general anaesthesia was performed

Social history

- Occupation and vocation
- Hobbies/sports/musical instruments
- Smoking/Alcohol/Drugs
- Driving status
- NOK contact details, and how the patients plan on getting to/from hospital
- Telephone number in case operation dates/details change and patient needs to be kept informed

Drug history

- Medications; Anticoagulants, Antiplatelets
- Allergies
- Immunisation status including tetanus cover in the past 10 years

- Any implanted devices/metal work including cardiac pacemakers, prostheses

Family history
Travel history
Psychiatric history
Forensic history

2.2 Examination

The patient should be approached with an ATLS algorithm so other potentially more significant injuries are not missed. After this the relevant upper limb injury can be examined in detail.

Examinations can be painful, but it is important to try and assess sensory changes before local anaesthesia is given, wherever possible.

A Look-Feel-Move approach can be taken for the examination;

Look:

- Skin
  - Open or closed
  - Pattern of injury
  - Erythema
  - Blistering
  - Swelling
  - Purulent collection or discharge
  - Bruising- if multiple with various ages, suspect NAI
  - Pallor
  - Skin loss, if so what structures needs cover, if there is sufficient soft tissue to cover bone and tendons, and what potential flaps or grafts could be utilised
- Site of injury
  - Laterality
  - Flexor or extensor zone

  - Volar or dorsal
  - Depth of injury
  - Communication with underlying structures, including bones or joints

- Type of injury
  - Bite/deep penetrating/abrasion/burst/degloving/amputation/avulsion etc.
  - Contamination status especially if marine, agricultural or sewage
  - Evidence of damaged structures
  - Active bleeding
  - Open fractures- need washout, IV antibiotics

- Deformity
  - Rotation/angulation/shortening/scissoring
  - Natural cascade of fingers with increasing flexion from index to little fingers at MCPJs and IPJs, and all fingers should point to the scaphoid tubercle
  - Use the tenodesis effect to check for cascade and potential tendon injury
  - Compare with contralateral (uninjured) hand wherever possible to detect abnormalities

- If patient is wearing a ring near the injury site, this should be removed where there is risk of oedema worsening and subsequent ischaemia

Feel:

- Skin
  - Temperature
  - Tenderness- assess pain with score out of 10
  - Sensation- this should be assessed prior to administration of local anaesthesia. Radial and ulnar aspects of digits should be quantified with a score out of 10, and with 2-point discrimination where possible (normally 2–3 mm at the fingertip).
  - Capillary refill time (normal <2 seconds at fingertip after pressing down for 5 seconds)

- Crepitus- feel for this in skin where there is concern of necrotizing fasciitis, or during movement of the joint which may indicate underlying osteoarthritis
- Tightness in the compartments, distal numbness and excruciating pain on passive extension of the digits or wrist is suggestive of compartment syndrome and can occur after crush injuries or high velocity injection injuries. Urgent decompression is often required through fasciotomies.

Move:

- Make a fist- this assesses global ROM in the hands and identifies any obvious abnormalities
- Flexion
  - Assess each finger in turn at the DIPJ and PIPJ. FDP can flex both DIPJ and PIPJ so isolate its function by having the hand flat, immobilizing the middle phalanx and examining DIPJ flexion (Fig. 2.1).
  - Assess FDS via flexion at the PIPJ and be sure to keep the other fingers in extension as FDS has a common muscle belly with tendons to the four fingers (Fig. 2.2).

FIGURE 2.1 Examining flexor digitorum profundus (FDP) of the right middle finger

Figure 2.2 Examining flexor digitorum superficialis (FDS) of the right middle finger

- FPL flexes the thumb IPJ and can be tested by fixing the MCPJ in extension and examining flexion at the IPJ.

- Extension
  - With all fingers fixed in flexion, examine each finger's extension against resistance in turn to assess EDC. Weakness or pain can suggest a partial or complete laceration that will require further EUA in theatre and potential repair.
  - EPL can be examined by having the hand flat on the table and asking patient to lift the thumb upwards towards the ceiling (Fig. 2.3) or fixing the MCPJ in a neutral position and assessing extension at the thumb IPJ.
  - EIP and EDM attach to the ulnar aspect of EDC and permit extension of the index and little fingers respectively, and independently of the other fingers. With the middle and ring fingers flexed, assess extension at the index and little finger to examine these two tendons.
  - Extensor lag is the term given to reduced active extension of the digit but passive extension may be normal. Lag at the DIPJ is suggestive of a mallet injury or

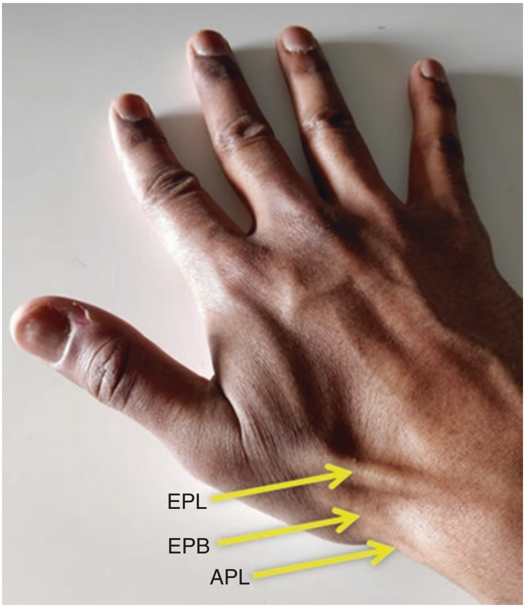

FIGURE 2.3 Examining extensor pollicis longus (EPL)

Seymour fracture, and lag at the PIPJ or MCPJ suggestive of damage to the EDC tendon. It is important to note that a small amount of extension may be maintained due to the action of juncturae tendinum from adjacent extensor tendons, or when only part of the tendon (such as the central slip or a lateral band) is damaged.

– Chronic central slip injuries cause a Boutonniere deformity. Central slip injuries can be identified easily using Elson's test, whereby the finger is bent at the PIPJ 90° over a table and the patient asked to extend the middle phalanx against resistance. If the central slip is damaged, there will be weak or absent extension at the PIPJ and a rigid DIPJ. If there is not a central slip injury, there will be extension at the PIPJ and the DIPJ will remain loose as the extension force is travelling through

the central slip and the lateral bands are not under tension.

- Adduction/abduction of fingers reflects actions of the palmar and dorsal interossei respectively and reduced action can suggest damage to the deep branch of the ulnar nerve which innervates them.
- Opposition reflects actions of opponens pollicis thenar muscle and the recurrent motor branch of the median nerve which innervates it.
- Deformity is particularly important after a fracture to indicate degree of functional damage and whether conservative or surgical treatment would be most effective. In particular the following should be commented upon and compared to the uninjured side where possible;
  - Rotation
  - Angulation
  - Scissoring when making a fist
  - Shortening

2.3 Investigations

These should be tailored to history and examination findings and be used to guide subsequent management;

- Bloods: useful for inflammatory markers in infection, baseline Hb and coagulation after haemorrhage, to check renal function, group & save for surgery.
- Imaging
  - X-ray radiographs for hand injuries with suspected underlying bony involvement, foreign body or osteomyelitis- ensure 3 views (AP, lateral, oblique) or specific scaphoid series in suspected scaphoid fractures

- If fractures are suspected and not clear on x-ray radiographs, particularly when carpal bone fractures are suspected, a CT is often required.
- If osteomyelitis is a concern, an MRI may aid clinical impression.
- Ultrasound can be used for concern over tendon rupture

Key Points

- A thorough history is crucial. If the patient is unresponsive, a collateral history can provide valuable clues.
- All patients should be approached with an ATLS algorithm initially.
- A look-feel-move technique can be used for systematic examination.
- Subsequent investigations can guide subsequent management.
- Ensure everything is documented clearly in the notes and relayed to the teams looking after the patient.

Chapter 3
Practical Notes in Hand Trauma

Zak Vinnicombe

In addition to clinical knowledge and surgical skill the application of practical components of plastic surgery is vital in hand trauma. This chapter will discuss initial practical management including dressings, splinting and sutures. It will also highlight practical management of anticoagulation, referral taking and trauma lists.

3.1 Dressings

Dressings constitute a fundamental role in plastic surgery; from initial management to post-operative care. There are a plethora of dressing types available on the market and familiarity with the basic principles of each is important.

Dressings should ideally:

1. Be comfortable for the patient
2. Protect wound from further damage
3. Create a good healing environment
4. Remove excess exudate
5. Allow good distal perfusion
6. Allow removal without traumatising wound bed or causing pain

Z. Vinnicombe (✉)
Department of Plastic Surgery, Royal Free Hospital, London, UK
e-mail: Zak.vinnicombe@nhs.net

P. Singh (ed.), *Hand Trauma in Clinical Practice*, In Clinical Practice, https://doi.org/10.1007/978-3-030-10844-1_3

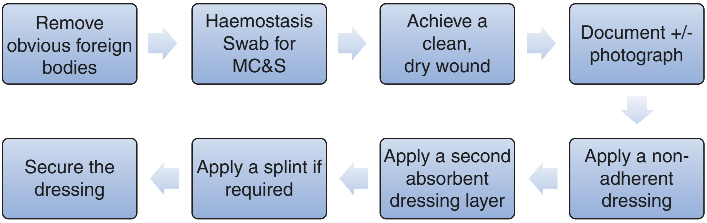

FIGURE 3.1 Stepwise practical management approach to hand trauma

In hand trauma, following a stepwise system for practical management will yield reliable and effective results (Fig. 3.1).

The primary dressing layer varies depending on the wound type (Table 3.1). For the absorbent second layer, sterile gauze is a readily available and an acceptable option. The choice of product for securing the dressing will vary depending on the location of the wound. Commonly used options are crepe, Easifix® and finger bandages (Fig. 3.2).

3.2 Splinting

Splinting is an important adjunct in hand trauma management. Plaster of Paris, Zimmer splints (finger splints) and thermoplastic splints are all useful when appropriately used. Splinting in combination with elevation is also effective for reducing pain and oedema post-injury. In principle, a splint should always immobilize the joint above and below the injury.

3.2.1 Plaster of Paris

Plaster of Paris (POP) is a useful tool for immobilisation, analgesia and protection. Between 8 and 12 layers is usually sufficient to provide support. Adding a longitudinal ridge into the plaster before it sets increases the strength, reduces the number of layers needed and reduces the weight of the cast

TABLE 3.1 Examples of common dressing types and their main uses

Dressing type	Description/Usage
Silicon based non-adherent dressing e.g. Mepitel®, Adaptic™, Silflex®	Provides a contact layer while allowing any exudate to pass through into second absorbent dressing layer. Minimises wound disruption and pain on removal. Can stay on for up to 7 days
Flamazine (containing silver sulfadiazine)	Infected, sloughy wounds. Should only be used in the short term. If wound is wet can macerate surrounding skin
Inadine™	Minor skin wounds. Should be changed after 48 hours once becomes dry and changes colour to white
Jelonet©	Open weave cloth soaked in paraffin. Good for keeping wounds moist. Useful for wounds on the ear as can be easily molded
Hydrocolloid fibres (e.g. Aquacel™)	Highly exudative wounds. Turns exudate into a gel. Can be used in combination with other dressings for exudate management
Alginates (e.g. Kaltostat®/Sorbsan®)	Absorption of wound exudate and haemostasis. Can adhere to non-exuding wounds making removal painful. Can be used for pre-tibial haematomas
Honey dressings	Anti-microbial. Sloughy and stagnating wounds. Good at lifting eschar
Hydrocolloids (e.g. Duoderm™, Granuflex®)	Can be used as a primary or secondary dressing. Can promote autolytic debridement of dry or necrotic wounds and promote granulation. Good for finger injuries to encourage mobility

for patients [4]. A protective soft layer must be applied beneath the POP, examples include Velband® and Soffban®. Take care to apply extra padding to bony prominences at the wrist and base of the thumb to prevent pressure lesions.

Figure 3.2 When applying finger dressings it is important to cut the bottom part of the dressing roll off so as not to tourniquet the finger

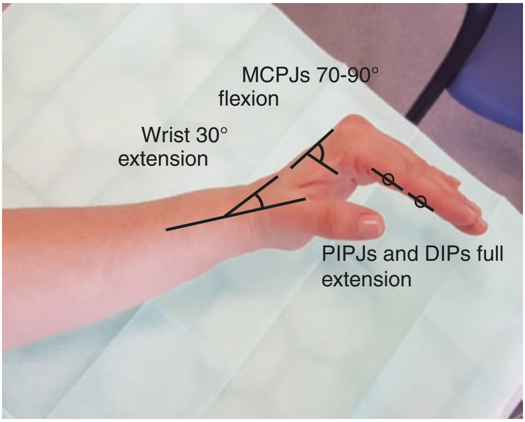

Figure 3.3 Position of safe immobilisation of the hand

A volar slab with the hand and wrist in the position of safe immobilisation is a safe option for most hand injuries (Figs. 3.3, 3.4, 3.5, and 3.6). The Position of Safe Immobilisation (POSI), also known as the intrinsic plus position or Edinburgh position,

FIGURE 3.4 Plaster of Paris in POSI. The plaster extends from the proximal forearm to the fingertips

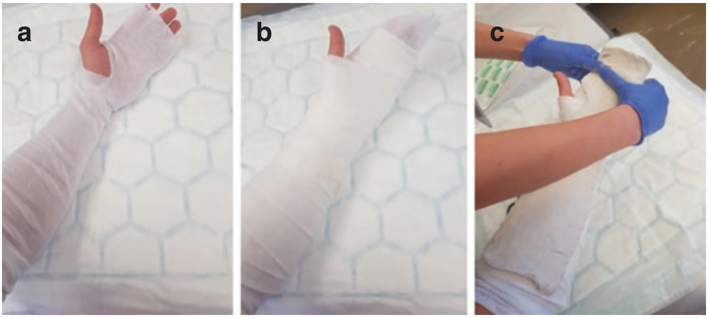

FIGURE 3.5 (**a**) Initial elastic bandage layers (**b**) Protective wool layer (**c**) applying the POP to the volar side of the forearm and hand, smoothing and molding the plaster to create a good fit

should be utilised for immobilisation of the hand to minimise stiffness and contractures and provide pain relief. It is also used after extensor tendon repair to minimize excessive tension over the repair and re-rupture. The shape of the metacarpal head means that when the MCPJ is in flexion the collateral ligaments are tight. This is known as the 'cam effect'. Collateral ligaments of the PIPJ and DIPJ are pretensioned when the

joints are in extension, thereby reducing contractures when the hand is immobilised for extended periods.

Step by step volar slab (Figs. 3.5 and 3.6)
There are other splinting methods available. The choice of splint varies depending on the situation.

Thumb spica (Fig. 3.7): This is a useful splint for injuries to the proximal phalanx of the thumb, first metacarpal fractures (including Bennett and Rolando fractures) and collateral

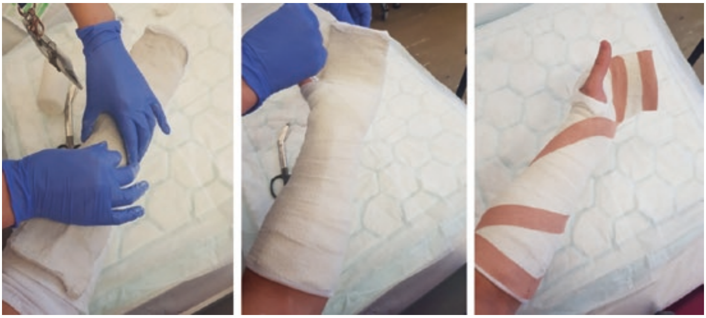

FIGURE 3.6 (**a**) Creating a ridge for extra strength (**b**) Covering the POP with crepe bandage (**c**) securing the crepe bandage with tape

FIGURE 3.7 Thumb spica using Plaster of Paris. If the thumb is being immobilized for a tendon injury then the cast will need to extend past the IPJ. Plaster is applied to the volar side of the forearm and molded around the thumb. It ends proximally below the elbow

FIGURE 3.8 Ulnar gutter cast. The POP is applied to the ulnar side of the forearm and extends to the black line on the volar side. Bandage layers can just be applied around the little and ring fingers to leave other fingers completely free

ligament injuries to the thumb. It allows the fingers to be mobilized as required.

Ulnar gutter cast (Fig. 3.8): This is similar to the volar slab but usually only immobilises the little and ring fingers. The position of the MCPJ and IPJs should be in the POSI. It can be used for fourth and fifth metacarpal fractures and has the advantage of leaving other fingers free to prevent unnecessary immobilization and stiffness.

Dorsal splint: This splint is similar to the volar slab and provides dorsal support to fractures, dislocations and subluxations. It is also often used post-operatively for flexor tendon injuries to prevent excessive tension on the repair. In this case the wrist is often not positioned in the full 30° of extension.

3.2.2 Finger Splinting

For more distal injuries metal splinting may be appropriate. These splints do not come premade and require cutting and molding prior to use. The edges of the splint are sharp when

cut and require rounding and covering with tape to prevent injury to the patient (Fig. 3.9). When splinting fingers it is important to remember that the MCPJ is at the level of the distal palmar crease. It is useful to mold the splint on the uninjured side prior to application.

Volar splint The metal splint can be used to immobilize the interphalangeal joints (Fig. 3.10). It can be used for extra-

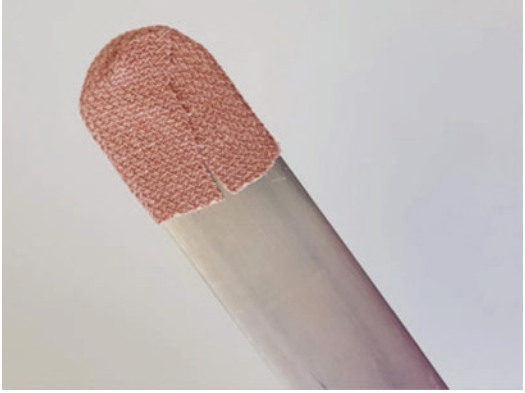

FIGURE 3.9 The ends of metal finger splints are sharp once cut and should be rounded and covered to prevent injury to the patient

FIGURE 3.10 A volar splint applied to the middle finger

FIGURE 3.11 A dorsal blocking splint with the DIPJ also immobilised. More pronounced flexion at the DIPJ and PIPJ may be required to adequately reduce and support a fracture, dislocation or subluxation

articular fractures of the phalanges and volar dislocations and subluxations which have been reduced.

Dorsal blocking splint These are effective splints for preventing full extension at both proximal and distal interphalangeal joints (Fig. 3.11). The phalanx distal to the bend in the splint can be left free allowing flexion in order to prevent stiffness. These splints are useful for volar plate injuries and reducible FDP avulsion injuries.

3.2.3 *Thermoplastic Splinting*

These type of splints are often applied once the hand therapy team start to see a patient for rehabilitation post-injury (Fig. 3.12). They have several advantages over Plaster of Paris in that they are:

- Re-moldable – helpful once oedema has reduced
- Lighter than POP
- Waterproof and easily cleaned

Figure 3.12 Examples of thermoplastic splints (**a**) volar splint after extensor tendon injury (**b**) dorsal blocking digital splint (**c**) Splint after EPL repair

3.3 Sutures and Wound Closure

3.3.1 Sutures

Sutures are a key tool for accurate wound edge apposition and repair of damaged structures. Their use for wound management includes repair of nailbeds, closure of deep tissues and tacking skin edges prior to theatre intervention. Suture preference will vary between centres. There are a variety of suture types available (Table 3.2) and the length of time needed before removal depends on the area they are used (Table 3.3). Tendons, nerves and arteries are most often repaired using non-absorbable suture types under loupe or microscope magnification.

The ideal suture:

- Causes minimal tissue reaction
- Maintains good tensile strength for all closures
- Inexpensive
- Resistant to shrinkage
- High tensile strength

Suture types can be divided into:

- Natural (N) vs. Synthetic (S)
- Absorbable (A) vs. Non-absorbable (NA)
- Braided (B) vs. Monofilament (M)

TABLE 3.2 Examples of sutures used in hand trauma, absorption times and common uses

Suture	Suture type	Absorption/ removal	Use
Vicryl rapide™	S, A, B	Strength loss: 7–10 days Absorbed: 40 days	Closure of simple hand lacerations. Lacerations in young patients or those who are unlikely to return for suture removal
Vicryl® (Polyglactin 910)	S, A, B	Strength loss: 21 days Absorbed: 90 days	Deep dermal sutures for closure of potential space in deeper wounds
Monocryl® (Poliglecaprone 25)	S, A, M	Strength loss: 21 days Absorbed: 90 days	As for Vicryl®
Ethilon® (Nylon - Polyamide)	S, NA, M	Needs removal	Wound edge apposition, closure in theatre. Advantage of less local tissue inflammation than absorbable sutures.
Prolene® (Polypropylene)	S, NA, M	Needs removal	As above. Useful for tacking open wounds together as a bridging measure before theatre.

3.3.2 Steristrips and Skin Glue

Although many lacerations will require sutures for satisfactory wound edge apposition there are other useful tools available for skin closure.

Table 3.3 Guidelines for removal of non-absorbable sutures

Location	Time to removal (days)
Hands	10–14
Face	5
Eye	3–4
Scalp	10–14
Legs	14
Back	>14

In shallow lacerations, where closing the epidermis would not create unsatisfactory wound edge tension and potential dead space beneath the closure, both steristrips and skin glue are viable options.

Steristrips can also be used for the inset of composite grafts after fingertip amputations in children. They have the advantage of not requiring any anaesthetic (either local or general) and being quick and easy to apply.

3.4 Anticoagulation

Dealing with patients on anticoagulation can often add complexity to a trauma situation. The management differs between patients on Direct Oral Anticoagulants (DOACs) and Warfarin. Not all surgeons will stop anticoagulants prior to procedures on the hand if the procedures are considered to be a low bleeding risk. There will often be local policies for perioperative management of anticoagulants so always refer to these where available. Below is some general guidance on the management of Warfarin and DOACs in surgery [1, 2].

3.4.1 Warfarin

For elective procedures Warfarin is often stopped 4 days before to allow INR to return to a normal range. The half-life

of Warfarin is highly variable and normally ranges 20–60 hours. A patient's level of risk will determine whether bridging therapy with low molecular weight heparin (LMWH) or unfractionated heparin (UFH) is required.

Low risk

- Target INR 2.0–3.0 for VTE >3 months or non-valvular AF unless TIA/CVA in last 3 months.
- No bridging anti-coagulation is required pre-operatively.

Intermediate risk

- Target INR 2.0–3.0 but VTE 6–12 weeks ago or valvular AF.
- Bridging prophylactic dose of LMWH with omission on morning of surgery is appropriate.

High risk

- Target INR 3.0–4.0 or any VTE within the last 6 weeks.
- Bridging therapeutic dose of LMWH with omission on morning or surgery is appropriate.

Very high risk

- Patients with mechanical heart valves.
- These patients are complex and will usually need discussing with haematology pre-operatively.
- There is an option of bridging with intravenous UFH pre-operatively, stopping 4 hours prior to surgery.

Restarting Warfarin Providing there is no excessive bleeding risk and the INR is <1.5, Warfarin can be restarted on the evening of surgery. There are a number of different reloading protocols, for example 1.5× patient's usual dose for 3 days followed by normal dosing after. This will vary depending on the local anticoagulation policy.

Bridging therapy Bridging therapy is the use of treatment dose LWMH or UFH to anticoagulate a patient while Warfarin is being reloaded. As the DOACs reach peak concentration more rapidly, bridging therapy is not required with them. Always refer to local protocols where available. Bridging is often required for patients deemed high risk of thrombosis.

Bridging therapy is not required for the following low risk patients [3]:

- Patients who have not had a stroke or TIA in the last 3 months
- Have a history of VTE but >3 months ago
- Have a CHA_2DS_2-VASc score ≤4 (Table 3.4)

Patients in whom bridging therapy should be considered:

- Warfarin for VTE treatment for which;
  - VTE <3 months ago
  - VTE whilst on therapeutic anticoagulation with target INR 3.5
- Warfarin for stroke/TIA prevention in AF for which;

Table 3.4 CHA_2DS_2-VASc score

Risk Factors	Score
Congestive heart failure	1
Hypertension	1
Age ≥75	2
Age 65–74	1
Diabetes mellitus	1
Stroke/TIA/thromboembolism	2
Vascular disease	1
Female Sex	1

- Stroke/TIA <3 months
- Previous stroke/TIA + 3 or more of
  - Congestive cardiac failure
  - Hypertension (140/90 mmHg or on medication)
  - Age >75 years
  - Diabetes mellitus

- Mechanical Heart Valves (other than those with bi-leaflet aortic valves).

Patients prescribed LMWH as VTE prophylaxis alone with no other thrombotic risk factors do not need this continuing on discharge. This includes patients whose anticoagulation has been restarted and do not require bridging therapy.

Reversal of warfarin pre-operatively In many trauma situations it may not be possible to wait for a patient's INR to normalize prior to surgery. In these cases there are several options available;

1. Vitamin K
   - Warfarin is a vitamin K epoxide reductase inhibitor. It has the action of reducing amounts of available vitamin K and therefore affecting the vitamin K dependent clotting factors (II, VII, IX, X).
   - Doses will vary depending on local protocols and it takes approximately 6 hours for vitamin K to reverse the anticoagulant effect of Warfarin.

2. Prothrombin Complex Concentrate (PCC)
   - Contains either 3 or 4 of the vitamin K dependent clotting factors. Beriplex® and Octaplex® are commonly used in the UK and contain all 4 coagulation factors (II, VII, IX, X) as well as protein C and S which are important in coagulation.

– The onset of PCC is rapid and a decline in INR occurs within 10 min, with the effects lasting 6–8 hours.

– PCC should be used after discussion with the Haematology team.

3.4.2 Direct Oral Anticoagulants (DOACs)

Direct oral anticoagulants (DOACs) target thrombin and factor Xa in the coagulation cascade. Rivaroxaban, Apixaban and Edoxaban are examples of direct factor Xa inhibitors and Dabigatran is a direct thrombin (IIa) inhibitor. The half-lives of the DOACs are significantly shorter than that of Warfarin (Table 3.5). This means they require a shorter period of omission prior to surgery.

Like Warfarin, there are often local policies in place for perioperative management of DOACs. It is important to consider a patient's renal function as this alters the half-life.

If the patient has normal renal function (i.e. CrCl >80 ml/min) the DOACs should be held for **24 hours** prior to surgery. Variations depending on renal function include:

– Rivaroxaban/Apixaban/Edoxaban: CrCl 30–50 ml/min – hold for 36 hours.
– Dabigatran: CrCl 50–80 ml/min – hold for 36 hours; CrCl 30–50 ml/min – hold for 48 hours.

If haemostasis is achieved and there is no further surgery is planned, then the DOAC can be restarted at the pre-operative dose 6–8 hours post wound closure.

Table 3.5 Common DOACs and their half-lives

DOAC	Half-life (hours)
Dabigatran	12–17
Rivaroxaban	5–9
Apixaban	~12
Edoxaban	10–14

3.5 Admitting Patients & Time to Theatre

The plastic surgery junior encounters a wide variety of hand trauma, most of which are discussed in this book. It is important to know the clinical urgencies for different presentations and the timeframes for theatre. Booking cases for an adequate amount of time will also aid in the smooth running of the trauma list.

Some cases require admission and booking for urgent theatre whereas others can be brought back to theatre as day cases. Common presentations and the guideline time for theatre are shown in Table 3.6. These are not absolute timings and will vary depending on the clinical presentation.

3.6 Taking a Referral

A significant part of the workload for plastic surgery juniors is taking and triaging referrals. Although most referrals from outside hospitals can be seen the next day there are several presentations that will need to be brought over urgently.

It is important to take a comprehensive referral with attention paid to salient points in the history. Most of these points will also be relevant when taking a history from a hand trauma patient.

Taking a '**HAND TRAUMA**' referral serves as an aide memoire;

- **H**OSPITAL REFERRING
- **A**GE/DOB OF THE PATIENT
- **N**AME OF THE PATIENT
- **D**OMINANT HAND**/D**ESCRIPTION OF THE INJURY
  - Handedness
  - Anatomical location of injury.
  - Position of hand at time of injury etc.
- **T**IMING OF INJURY
  - Important for revascularisations, replants and infections

TABLE 3.6 Common hand injuries, their urgency for theatre and guideline theatre time

Injury	Time to theatre	Theatre time (hours)
Replantation and revascularisation	**ASAP.** Digits can tolerate 6–12 hours of warm ischaemia and 12–24 hours of cold ischaemia. Amputations containing muscle tolerate significantly less ischaemia time	**4–6**
Flexor sheath infection	**ASAP.** Patients with flexor sheath infections are an emergency	**1**
Severe infections	**ASAP.** Similar to flexor sheath infections	**1**
Open fractures	**<24 hours.** Early irrigation and IV antibiotics is also part of management.	**1–2** (Depending on severity)
Bite injuries	**<24 hours.** Some more minor injuries may be debrided under LA in A&E or clinic. Fight bite injuries in particular need to be booked for theatre for joint washout	**1**
Other infections	**<24 hours** Less severe infections may be management conservatively with regular reviews.	**1**
Open tendon injuries	**<3 days** Have better outcomes when done early. Good initial wound care important	**1 – extensor** **2 – flexor**
Nailbed injuries	**<3 days** In adults can often be done under LA in clinic.	**1**
Nerve injuries	**<7 days**	**1**
Closed injuries (fractures, tendons, ligaments)	**<7 days** Severely displaced fractures requiring early MUA may need theatre sooner if difficult reduction. Many closed fractures can be conservatively managed with appropriate splinting and follow up radiograph in 7 days. If you are unsure on the management of a fracture always consult a senior.	**2** (+1 for each additional fracture)

- – Patients **requiring admission** and theatre ASAP
- –Patients **usually requiring admission** and theatre within 24 hours
- – Patients **not routinely requiring admission**

- **R**EASON FOR INJURY
  - What is the mechanism of the injury? Is the wound likely to be contaminated? What material caused the injury? If machinery, what is it used for?

- **A**SSESSMENT OF STRUCTURES

  - **Vascularity** – Evidence of perfusion distal to the injury? Digit/area warm and pink? Capillary refill time? Evidence of venous congestion? Pulse oximetry on injured finger(s)? Values of >95% suggest no vascular injury
  - **Nerves** – Paraesthesia or reduced power?
  - **Tendons** –Loss of hand function due to tendon injury? Can any tendons be visualised in wounds? Is there weakness or pain on tendon testing?
  - **Bones** – Any bony injury? If so, open or closed injury? (this is important as management for open vs closed is significantly different)
  - **Skin –** Is there skin loss or impending skin loss?

- **U**P-TO-DATE TETANUS/**U**P TO DATE BLOODS

  - Up to date with tetanus vaccination? Is this a tetanus prone wound and do they require tetanus immunoglobulin? Do they need a tetanus booster?
  - Have they had blood tests? If infection suspected what are the inflammatory markers?

- **M**EDICAL HISTORY/**M**EDICATIONS/**M**ANAGEMENT SO FAR

  - Significant past medical history? Any medications, particularly blood thinners? Initial management? Any antibiotics or other drug treatment given?

- **A**DVICE

  - General wound management advice. Irrigation with 1 L saline or running tap water (1 min under constant running tap water is the equivalent of 2–3 L of irrigation). Dressing advice as described in this chapter. Almost all

hand trauma patients require plain film radiographs (AP and true lateral). These should be sent electronically from the referring hospitals.

In this chapter we have reviewed some of the more practical elements of hand trauma. Each unit and each individual surgeon will often have their own preferences for many of the areas discussed above. It is however important to have an understanding of the core principles of practical management. Special thanks to the Plastic Surgery Nursing team and Hand Therapy team at the Royal Free Hospital and St. Thomas' Hospital for their help with this chapter.

References

1. Guy's and St. Thomas' NHS Foundation Trust. Perioperative bridging of warfarin in adult patients undergoing elective surgery. London: Guy's and St. Thomas' NHS Foundation Trust; 2018.
2. Guy's and St. Thomas' NHS Foundation Trust. Perioperative surgical bridging protocol for patients receiving Direct Oral Anticoagulants (DOACs). London: Guy's and St. Thomas' NHS Foundation Trust; 2018.
3. Keeling D, Campbell Tait R, Watson H, on behalf of the British Committee for Standards in Haematology. Perioperative management of anticoagulation and antiplatelet therapy. Br J Haematol. 2016;175:603–13. https://doi.org/10.1111/bjh.14344.
4. Theopold C, Bush JA, Wilson SW, Bayat A. Optimal plaster conformation derived using a custom-made jig to obtain maximum strength of protective plaster of Paris for hand surgery. J Trauma: Injury, Infection, and Critical Care. 63(5):1074–8.

Chapter 4
Soft Tissue Injuries

Kapila Mendis

Soft tissue injuries comprise a significant amount of hand trauma injuries. Knowledge of commonly injured structures and how best to manage them is crucial.

Soft tissue reconstruction in the hand, especially in the digits is challenging to anyone managing these injuries. Available options vary from conservative management all the way up the reconstructive ladder to free tissue transfers requiring microsurgery. The ultimate goal is to achieve stable, mobile and sensate digits with an adequate soft tissue envelop [1] allowing for functional and aesthetic outcomes. Depending on the reconstructive procedures undertaken, rehabilitation duration and intensity can vary significantly.

4.1 Fingertip Injuries

Fingertip injuries are common and often result from sharp lacerations, crush, avulsion or penetrating injuries. A goal of reconstruction is to provide a durable sensate fingertip for the patient [1].

K. Mendis (✉)
Department of Plastic Surgery, Royal Free Hospital, London, UK

P. Singh (ed.), *Hand Trauma in Clinical Practice*, In Clinical Practice, https://doi.org/10.1007/978-3-030-10844-1_4

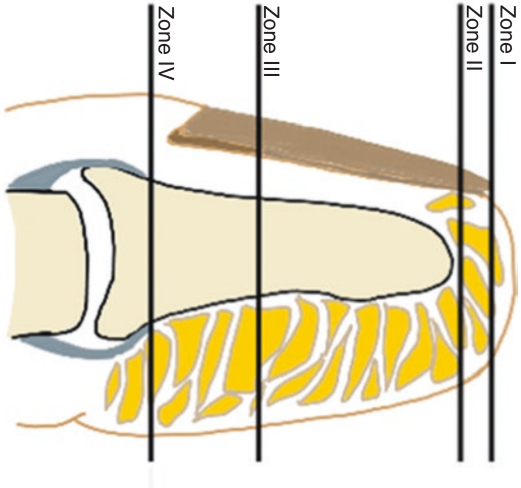

FIGURE 4.1 Allen's classification for amputations of the distal

Allen's classification for amputations of the distal phalanx divides the fingertip in to four zones (Fig. 4.1) [2];

Zone 1: Involving pulp only
Zone II: involving pulp and nail bed
Zone III: Involving pulp, nail bed and part of distal phalanx
Zone IV: pulp, nail bed, part of distal phalanx and lunula

Planes of injury in fingertip amputations can be described as dorsal oblique, volar oblique or transverse. Both zone and plane of injury are important factors on deciding future reconstruction.

Zone I transverse injuries will heal by secondary intension or primary closure. It is important to keep the nail bed shorter than the distal phalanx in order to prevent a hook nail. Where the amputated distal tissue is available, it can be placed back over the digit as a composite graft which acts as a biological dressing. This involves de-fatting of the amputated tissue and

tacking back in place using sutures or steri strips. Composite grafts tend to have better take in younger children.

Technique:

- The amputated tissue should be transported wrapped in saline soaked sterile gauze in a plastic bag, inside another plastic bag containing ice
- An x-ray radiograph of the distal and proximal digit should be done to assess bony involvement or exposed bone
- The nail should be removed and fat trimmed
- Tissue can be attached using absorbable sutures or steri strips

In more extensive tissue defects where healing by secondary intention is not a viable option, further reconstructive options can be considered;

- Skin grafting – split or full thickness skin grafts can be used if no bone is exposed
- Local flaps
    - From same digit (homodigital):
        - Atasoy V-Y flap
        - Venkataswami flap
        - Moberg flap
        - Homodigital island flap
        - Transposition flap
    - From adjacent digits (heterodigital):
        - Cross finger flap for volar defects
        - Reverse cross finger flap for dorsal defects
        - FDMA (First dorsal metacarpal artery)/Kite flap/ Foucher's flap
        - Reverse radial forearm flap for thumb defects
    - From palm:
        - Thenar flap is a useful option for children with middle or ring fingertip injuries

- From abdomen:
  - Para umbilical flap
  - Groin flap with surgical syndactilisation of multiple digits
  - Pedicled groin flap for a single digit

These flaps are discussed in more detail in Chap. 8.

Terminalisation must be considered as an option depending on the severity of the injury in a non-replantable digit. A thorough discussion with the patient or parents/guardian is mandatory and should obtain an informed written consent.

4.2 Nail Bed Injuries

Nail bed injuries are common in all age groups and are often due to crush mechanisms. The nail bed is the tissue underlying the nail plate which facilitates smooth nail plate growth and adheres the plate to the underlying finger. It is a fragile bed of tissue which is prone to laceration following fingertip injury. This can cause communication with an underlying fracture should there be one, increasing the risk of osteomyelitis if not appropriately managed.

Signs of nail bed damage are a throbbing painful fingertip with a subungual haematoma, elevation of the nail plate off the bed, or laceration to the fingertip involving the nail. Subungual haematoma might require decompression for symptomatic relief [3] or removal of the nail plate.

A systematic history and examination is required (see Chap. 2) and subsequent imaging should include an x-ray radiograph of the digit to assess underlying bony injury. Tuft fractures are common and are treated by repair of the surrounding soft tissue to act as a splint.

Transverse distal phalanx fractures may require K-wire fixation to prevent deformity due to the pull of FDP volarly, or EDC dorsally, which can cause the fracture to slip leading to malunion or non-union.

The decision to repair a nail bed can be made on the degree of subungual haematoma; <25%, asymptomatic for conservative management with oral antibiotics cover, 25–50%

for trephination of the subungal haematoma, >50% or underlying fracture for definitive surgical repair.

Definitive nail bed repair is carried out to reduce the risk of osteomyelitis to potential underlying distal phalanx fracture as these are classified as open fractures, and to encourage smooth nail growth. A significant proportion of the nail plate growth comes from the germinal matrix, so damage here can result in abnormal or absent growth. Anaesthesia depends on age of the patient with adults and older children amenable to local anaesthetic ring blocks, and younger children usually requiring general anaesthesia. The operative technique is then the same;

- Prepare sterile field, clean and drape digit/hand,
- Confirm the anaesthetic block of digit and apply a finger tourniquet
- Elevate nail plate with Mitchell's trimmer off nail bed
- Apply an artery clip to one end of the nail plate and slowly rotate to remove nail plate.
- Wash fingertip with hydrogen peroxide 3% and remove subungual haematoma
- Repair of underlying nail bed laceration with Vicryl Rapide sutures (6/0 to 5/0 depend on age)
- If the laceration is more proximal, particularly in the germinal matrix, extend longitudinal incisions proximally to expose the laceration and repair. This is termed raising 'eponychial flaps.'
- Confirm removal of tourniquet
- Dress with Silflex/jelonet, gauze, finger bob or boxing glove if young children.
- Administer oral antibiotics 1 week
- Dressings clinic follow up to ensure no subsequent infection and appropriate healing

4.3 Seymour Fractures

Care must be taken to identify and manage Seymour fractures [4]. These are displaced distal phalanx fractures through the physis involving soft tissue becoming trapped within the

fracture which can then prevent bone union, resulting in malunion, non-union, growth arrest or chronic osteomyelitis.

The main differential diagnosis for a Seymour fracture is mallet finger. Mallet fingers are more often seen in adults and can be either soft tissue alone or accompanied by an underlying fracture. They can also be present in children, usually with Salter Harris type III or IV fractures which enter the DIPJ. Seymour fractures are seen in children as they require the presence of a growth plate but fracture lines do not enter the DIPJ. The flexion deformity is due to the unopposed action of the FDP tendon inserting into the metaphysis compared to the extensor tendon inserting in to the physis. The original classification by Seymour was [4];

1. Metaphyseal fractures 1–2 mm distal to epiphyseal plate
2. Salter Harris I
3. Salter Harris II

After removing the soft tissue from the fracture site in a Seymour fracture, if the fracture is stable it can be managed conservatively with a splint and close observation. If the fracture is unstable, an axial K-wire placed under image intensifier may be required. This can then be removed in 3–4 weeks.

4.4 Closed FDP Avulsion Injuries

These injuries involve avulsion of the FDP from the base of the distal phalanx and are classified by the Leddy Packer classification [5];

- Type I- FDP tendon retracts to palm + vinculae disruption. Surgery required <1 week.
- Type 2- FDP tendon retracts to level of PIPJ. Surgery required <2–3 weeks.
- Type 3- Large avulsion fragment of distal phalanx with FDP attached limits retraction to level of DIPJ. Surgery required <2–3 weeks.
- Type 4- Avulsion fragment of distal phalanx with avulsion of FDP not attached to fragment and retracted to palm.

Surgery required for ORIF then tendon re-attachment <1–2 weeks.

Type 5- FDP tendon retracted with avulsed osseous fragment + comminution of remaining distal phalanx.

Direct tendon re-attachment can be done via a direct tendon repair or mitec™ anchor if the injury is <3 weeks. An advancement of more than 1 cm of the FDP tendon can cause fiixed flexion contracture of the DIPJ or quadriga phenomenon.

4.5 Digital Nerve Repair

Digital nerves can be easily damaged by volar, radial or ulnar lacerations to hand or digits, or via deep penetrating injuries. Patients often complain of numbness, or pins and needles tingling distal to the laceration. Certain parts of the hands are important for sensation in the activities of daily living, and often this is reflected by having larger calibre neurones at these sites. These include the UDN of the thumb and RDN of the index finger (sensation to first web), UDN little finger.

It is important to establish whether a nerve has been cut (neurotmesis) or bruised (neuropraxia) as a cut nerve will need repair or grafting but a bruised nerve usually returns to function. A neuropraxic nerve should return to function after a few days depending on the severity of the injury, although often the differentiation is not clear until direct visualisation in theatre with magnification.

Digital nerve neurosynthesis or end-to-end nerve coaptation should be done in theatre under magnification with surgical loupes or a microscope, using 8/0 or 9/0 non-absorbable monofilament sutures such as S&T, place in the perineurium, aligning the Vasa nervorum. If the nerve repair is tight, a dorsal POP can be used initially then thermoplastic splint can be used to protect the nerve repair. Direct nerve coaptation is a practical option where there has been minimal loss of nerve length (length is often lost through bites or circular saw injuries) and the laceration is through a single plane. The main

reasons for nerve repair are to aid in neuronal continuation and a restoration of sensation, but perhaps more importantly to reduce the risk of neuroma formation which can be more painful. Neuromas are a painful nidus of nerve fibres which branch haphazardly from the proximal cut end of the nerve in a desperate attempt to re-establish nerve continuity. These can become very sensitive and painful.

Nerves will regenerate at 1 mm/day so patients should be forewarned of the slow rate of repair and to take care to minimise damage to insensate digits during this time.

References

1. Ramirez MA, Means KR. Digital soft tissue trauma: a concise primer of soft tissue reconstruction of traumatic hand injuries. Iowa Orthop J. 2011;31:110–20.
2. Allen MJ. Conservative management of finger tip injuries in adults. Hand. 1980;12:257–65.
3. Bennet JE. Skin and soft tissue injuries of the hand in children. Pediatr Clin N Am. 1975;22(2):443–9.
4. Seymour N. Juxta-epiphyseal fracture of the terminal phalanx of the finger. J Bone Joint Surg Br. 1966;48(2):347–9.
5. Leddy JP, Packer JW. Avulsion of the profundus tendon insertion in athletes. J Hand Surg. 1977;2:66–9.

Chapter 5
Hand Infections

Alexander Trevatt

Hand infections are commonly seen in A&E and by the plastic and orthopaedic surgery juniors. They can range from mild, superficial infections to severe limb and life-threatening ones. Knowing how to spot the difference, and how to manage them is critical. In this chapter we will discuss;

- *Flexor tenosynovitis*
- *Paronychias and Felons*
- *Spaces in the hand*
- *Bites*

5.1 Flexor Sheath Infection (Flexor Tenosynovitis)

Flexor tenosynovitis is infection within the flexor sheath. It is a clinical emergency as it can lead to destruction of the flexor tendon within 24 hours, and rapidly progress to sepsis. The most commonly found bacterial culprits are Staphylococcus aureus and Beta-haemolytic Streptococcus. It is important that bacterial pus swabs are taken during washout to isolate bacteria, as other causative pathogens could be liable and

A. Trevatt (✉)
Department of Plastic Surgery, Royal Free Hospital, London, UK

P. Singh (ed.), *Hand Trauma in Clinical Practice*, In Clinical Practice, https://doi.org/10.1007/978-3-030-10844-1_5

targeted antibiotics should be commenced as soon as sensitivities are known.

The clinical history may harbor clues to the underlying pathophysiology. In particular, bites, penetrating trauma, or retained foreign bodies may seed infection in to or adjacent to the flexor sheath. An underlying immunosuppressive condition such as diabetes mellitus or immunosuppressive medications often used in rheumatology or transplant patients could also explain the rapid development of a tenosynovitis. Smokers are also at higher risk.

Flexor sheath infection (Figs. 5.1 and 5.2) is a clinical diagnosis and thorough examination of the hand required. The hand and digits should be examined for neurovascular status, function, foreign bodies and contamination status, and imaged appropriately with x-ray radiographs. Kanavel described four cardinal signs of acute flexor synovitis [1] but it is important to remember than all may not be present, especially in early presentations and one should have a low threshold for treatment. Kanavel's signs are;

- Fusiform swelling of the digit
- Tenderness along the flexor sheath
- Pain on passive extension of the digit

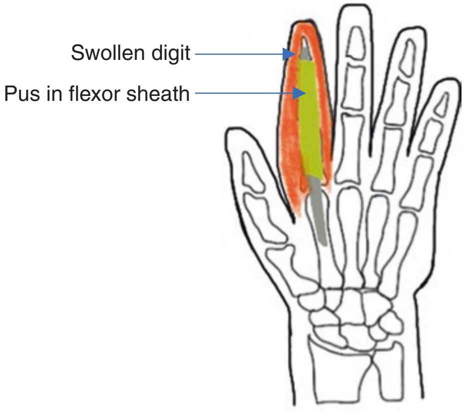

Figure 5.1 Diagram of flexor sheath infection

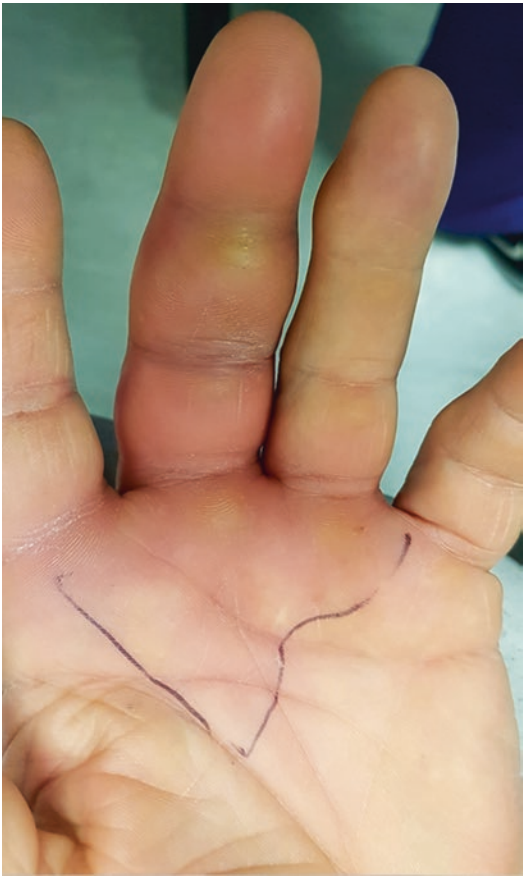

FIGURE 5.2 Photograph of flexor sheath infection

- Finger held in flexion

Further investigations include IV access and bloods including inflammatory markers, renal function and blood cultures. Radiographs will help identify the presence of a foreign body, osteomyelitis or underlying fracture.

Immediate management involves analgesia, IV antibiotics, elevation of the limb in a Bradford sling. The erythematous

area should be demarcated with a marker pen, and the date and time recorded. Any gross contaminants or foreign bodies should be removed in A&E and the limb cleaned. There should be early escalation and a plan for definitive washout in theatre.

The patient should be consented for a second washout within 48 hours if required; that there may be large scars in the hand and fingers if the infection is found to have spread and a more thorough washout required; that wounds may be left open to allow drainage of pus; there is likely to be stiffness and pain afterwards and a risk of CRPS in the future; and there may be damage to adjacent structures in the hand. The patient will likely require admission for further IV antibiotics, elevation and daily reviews for a potential return to theatre for subsequent washout.

Surgery should be performed under general anaesthesia.

- An arm tourniquet can be used **without** exsanguination to improve visualisation of the operative field. Exsanguination is avoided to prevent spreading infection proximally.
- In less severe cases, a minimally invasive flexor sheath washout can take place. An incision is made over the A1 and A5 pulleys in the midline of the digit and a large bore catheter inserted with saline flushed proximal to distal to wash out the flexor sheath.
- In severe infections an open debridement and washout is warranted with incisions along the finger using Brunner's or mid-lateral techniques. This can be extended in to the palm if required.
- The wound should be irrigated extensively with saline and betadine and with betadine-soaked ribbon gauze.
- Ideally the wounds should be left open or tacked loosely together, reviewed in the morning and given a 'betadine bath' wash.

IV antibiotics and elevation are required until resolution of infection with a low threshold for repeated washout in theatre. The patient should then be discharged with a short

oral course of antibiotics and early hand therapy to improve mobility as stiffness will likely be setting in.

5.2 Paronychias and Felons

Paronychias and felons are common infections in the hand. Paronychias involve the soft tissues around the nail (Fig. 5.3), and felons the multiple septal compartments of the fingertip pulp (Fig. 5.4). The septal compartments are separated by dense fibrous tissue, so infection in one leads to increased

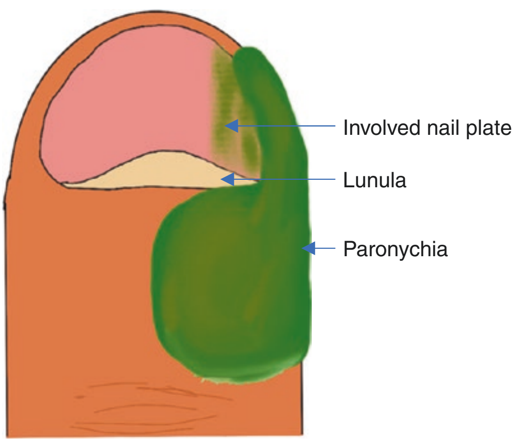

FIGURE 5.3 Paronychia

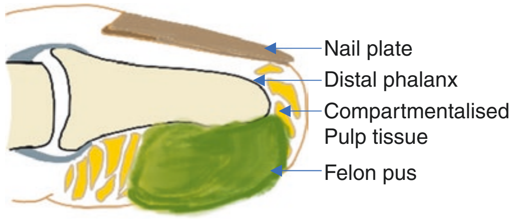

FIGURE 5.4 Felon

pressure, compartment syndrome and pulp necrosis if inappropriately managed. Paronychias and felons are found in separate anatomical spaces, making it unusual to have both at the same time in the same digit. The most common causative bacterium is Staphlococcus aureus.

A clinical history will often reveal predisposing injuries, in particular nail biting, manicures or gardening which can seed bacteria. Immunosuppression and smoking both increase the risk of these infections. A thorough examination of the hand is required, which will often reveal erythema, swelling, tenderness and a fluctuant, warm, purulent collection. X-ray radiographs may help identify foreign bodies or osteomyelitis and should be performed. Simple cases can be treated with incision and drainage in A&E, an oral course of antibiotics and follow up in a dressings clinic or by the GP. If systemically well, further management is not required.

Prior to surgical intervention, the patient should be consented for recurrence, poor scarring, absent or aberrant nail growth, particularly as the nail plate should be removed in paronychias.

In adults and older children incision and drainage can be performed under a local anaesthesia ring block.

For paronychias:

- LA ring block
- Prep and drape digit
- Sterilise digit with an iodine or chlorhexidine based solution
- Incise and drain collection with scalpel
- Pus swabs should be sent for MC&S
- If the infection is adjacent to or involving the nail, the nail plate should be removed
- Thorough wash with betadine and saline irrigation
- Dress digit, oral antibiotics and follow up in 48 hours in dressings clinic or GP

For felons:

- Incisions should be over the main point of fluctuance but without damage to important underlying structures and

minimising the risk of future scar contractures. Longitudinal incisions can be made in the midline of the finger pulp, with care taken to avoid crossing the DIPJ crease if possible. Incisions can also be made mid-laterally

- Thorough washout with betadine and saline
- Dress and follow up as with paronychias.
- Leave all wounds open so infection can drain over the subsequent days and healing will occur by secondary intention.

5.3 Spaces in the Hand

Infections in the hand can spread to various spaces and knowledge of these is important when carrying out washouts and decompressions (Fig. 5.5). Important spaces are;

- Thenar space: volar to adductor pollicis, dorsal to flexor tendons
- Hypothenar space: volar to fifth metacarpal, dorsal to hypothenar fascia
- Mid-palmar space: dorsoradial to hypothenar space in centre of palm
- Dorsum of hand: dorsal to extensor tendons
- Collar button space: in the webspace between fingers

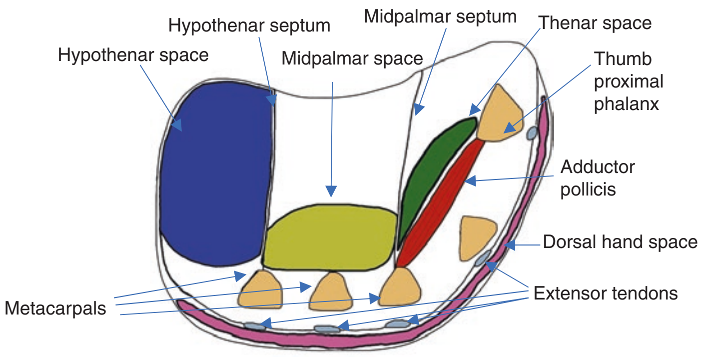

FIGURE 5.5 Spaces in the hand on axial cross section

- Carpel Tunnel: dorsal to flexor retinaculum
- Parona's space: volar to pronator quadratus and dorsal to FDP in the distal forearm, this space is continuous with radial and ulnar bursae and the mid-palmar space.

5.4 Bite Injuries

The bacterial type and load will depend on the oral constituents in the mouth of the culprit dog, cat or human. Common causative bacteria include Staphylococcus aureus, Staphylococcus viridians and Pasturella multocida, which can seed the wound and particularly dermal edges and can penetrate in to deeper structures.

Dogs have powerful jaws and serrated teeth which cause crush and tear lacerations, resulting in significant damage to structures with loss of tissue and underlying crush fractures. Cats have sharp penetrating teeth which can seed bacteria deep within the tissue and in to joints. As cat bites are less likely to be open, drainage is reduced, and deep-seated infections can harbor and become more severe. Human bites contain high bacterial concentrations and potentially viruses including HIV, Hep B and Hep C.

The history will give clues to the injury and time that the infection has been progressing. For bites, A&E often have a proforma that must be filled out and for animal bites, often the police will get involved where the injury is severe or the animal thought to be a threat. Careful documentation and photography is therefore crucial.

Examination should be thorough and assess for function and neurovascular status. Puncture wounds or lacerations over tendon sheaths or joints are particularly concerning and need urgent washout to prevent tenosynovitis or septic arthritis. X-ray radiographs are useful to determine underlying bony injuries or foreign bodies, such as teeth.

Immediate management depends on the extent of infection. Early presentation following bites where no infection is present warrants:

- Washout under local anaesthetic
- EUA of underlying structures
- Debridement of skin edges as these contain high bacterial load
- Discharge with oral antibiotics, tetanus and follow up review in 48 hours

Active infection warrants:

- IV antibiotics
- Demarcation of erythematous region with date and time
- Washout under local anaesthetic with iodine and saline
- Debridement of skin edges
- Leave wounds open to drain and pack with betadine soaked ribbon gauze
- Elevation of hand in Bradford sling
- Consideration for further washout in 48 hours or to repair structures
- Bloods including cultures, HIV, Hep B, Hep C
- For severe injuries involving shortened, fractured or comminuted bone, an ex-fix may be placed as a temporising measure whilst the infection resolves, before consideration of an ORIF and repair of structures at a later date.

Reference

1. Kanavel AB. The symptoms, signs, and diagnosis of tenosynovitis and fascial-space abscesses. In: Infections of the hand. 1st ed. Philadelphia: Lea & Febiger; 1912. p. 201–26.

Chapter 6
Hand Emergencies

Christopher Deutsch

Hand emergencies cover a spectrum of pathologies which must be urgently dealt with. The following topics are covered in this chapter;

- Digit replantation
- Devascularised digit
- Open fractures
- Extravasation
- Compartment syndrome
- Burns

6.1 Digit Replantation

Traumatic digital amputations are not uncommon injuries, and are usually caused by power tools, blades or high energy impacts. The two options for management are essentially replantation or terminalisation.

Which option to take depends on numerous factors. Generally, replantation should be attempted for the thumb at almost any level, if multiple digits are involved, in children, if the amputation is at the level of FDS insertion or proximal. In general, replantation is not attempted for amputations

C. Deutsch (✉)
Department of Plastic Surgery, Royal Free Hospital, London, UK

P. Singh (ed.), *Hand Trauma in Clinical Practice*, In Clinical Practice, https://doi.org/10.1007/978-3-030-10844-1_6

distal to the level of FDS insertion is a single digit, if the tissue is infected, if there has been prolonged ischaemia time, or in medically or psychiatrically unstable patients.

Digital replantation is a technically challenging procedure associated with a relatively high failure rate and poor functional outcome. The decision to perform a replant should therefore not be taken lightly. Factors making replantation an unfavourable option include a long ischaemic time, inappropriate storage of the amputated part, amputation associated with shearing, degloving or blunt force, other injuries or a patient who smokes or has significant co-morbidities.

Commonly cited relative indications for attempting replantation are:

- Thumb amputation
- Paedatric patients
- Amputation distal to the insertion of FDS
- Multiple digits

A patient presenting with an amputated digit should be managed as an emergency and will require the following:

- Analgesia
- Intravenous access
- Routine blood tests
- Intravenous antibiotics
- Tetanus vaccination
- Wound photography
- Radiographs of the proximal end and amputated part
- The amputated part should be stored in a sterile saline soaked gauze, inside a plastic bag, within another plastic bag containing ice and water.

If replantation is to be attempted in theatre, the patient must be informed that the procedure can be unsuccessful, and consequently terminalisation may be needed either in theatre or at a later date. They must also be prepared for fusion of the joints if necessary, either permanently or temporarily.

In theatre, replantation follows a fairly predictable surgical sequence:

- General anaesthesia
- Arm tourniquet
- Prepare and drape the hand, and prepare the amputated component with antiseptic solution
- Assess the proximal end and amputated tissue under the microscope, debride devitalised tissue and fat, and identify and dissect out arteries, veins, nerves and tendons.
- Fixation of bony fragments
- Repair of flexor and extensor tendons
- Arterial repair: one digital artery is usually sufficient. A vein graft may be required.
- Venous repair: without which venous congestion will cause loss of the replant. A vein may be required
- Digital nerve repairs
- Primary closure, skin graft or local flap to cover exposed structures
- A protective POP should then be applied, with the fingertip exposed for monitoring

Post-operatively inpatient admission is required to monitor the distal tissue with hourly observations for congestion, ischaemia or infection. Venous congestion is a common complication and can be managed by prick with a blue needle to encourage bleeding, assisted by heparin-soaked gauze on top. Leeches can also be used for exsanguination, and prophylactic ciprofloxacin should be prescribed alongside to minimise infection from Aeromonas species co-existing with the leeches. Allowing a congested digit to bleed can rescue it but this technique should be used carefully, particularly in children, as a surprising volume of blood can be lost over time. Intravenous antibiotics should be continued over time, and eventually hand therapy.

6.2 Devascularised Digit

Deep lacerations and ring avulsion injuries to the volar finger can result in injury to both neurovascular bundles and subsequently cause digital ischaemia. If an injured finger is cold,

pale or completely insensate, an urgent exploration is warranted.

Microsurgical repair of the vessels in theatre should be performed as early as possible, as it is not possible to keep the digit cooled. The surgical approach is similar to digital replantation, but often veins do not need to be repaired as the dorsal venous supply is usually maintained.

These injuries are serious, and patients must therefore be aware of the risk of failure to re-establish a blood supply and that the finger may need to be terminalised.

6.3 Open Fractures

Open fractures are common in the hand. They are usually associated with high-energy injuries, assaults or crush injuries. They require urgent intervention due to the high risk of developing osteomyelitis when they are not managed appropriately. The only exception is tuft fracture of the distal phalanx with associated nailbed injury, which can be managed with oral antibiotics and nailbed repair.

As with any hand injury, the patient must be clinically assessed with a history to include the nature of the injury and risk of any gross contamination. Injuries sustained in the context of marine, sewage or agricultural environments are particularly high risk. Radiographs with three views are required to assess both the fracture and the presence of any foreign bodies.

Immediate management can be instigated in the Emergency Department. The wound should be irrigated with saline under local anaesthetic block to remove any large foreign bodies or gross contamination. The fracture can be reduced if it is needed to help control the patient's pain, but the distal neurovascular status should be checked before and after fracture reduction. The patient should be admitted for intravenous antibiotics and consented for formal surgical washout and fracture fixation. Surgery should be arranged for the next operating list, within 12–24 hours, but rarely needs to happen overnight if there is no vascular compromise.

6.4 Extravasation Injuries

Extravasation injuries occur when intravenous infusions leak from or around an intravenous cannula, into the surrounding soft tissue. They are common after misplacement or dislodgement of a cannula and must be appropriately managed. Management depends on the history, and particularly on the extravasated chemical.

These issues must be addressed:

- What was the substance? They can be classified as vesicant (e.g. vincristine), irritant (e.g. cisplatin), non-vesicant (e.g. bleomycin) and neutral (e.g. 0.9% saline solution).
- How much volume has been extravasated?
- How long ago did it happen, and at what rate was the infusion running?
- What changes have occurred to the patient systemically or locally to the surrounding soft tissue?
- What immediate first aid was given?

Examining the area determines the next steps, and so these features must be considered:

- Damage to the overlying skin, particularly evidence of necrosis
- Firm compartments, suggesting compartment syndrome
- Pain on active or passive movement
- Fixed positional deformities
- Reduced function of the hand
- The presence of pulses and sensation

Where the extravasation has happened some time ago and there are no evolving changes, reconstruction of the resulting defect may be the only remaining task. However, extravasation is usually identified early, and emergency action can prevent significant tissue damage.

Immediate management includes:

1. Stop the infusion
2. Elevate the limb

3. Demarcate the areas of skin changes with the date and time
4. Analgesia
5. Cold compression or warm compression depending on the chemical (Table 6.1)
6. Incisions, infiltration of hyaluronidase and flushing with saline may be needed
7. Necrotic skin will need debridement

Table 6.1 List of items requiring cold vs. warm compression

Cold compression (DNA-binding vesicants, irritants, non-vesicants)	**Warm compression (Non-DNA-binding agents)**
Amsarine	Cabazitaxel
Dactinomycin	Docetaxel
Epirubicin	Paclitaxel
Mitomycin	Vinblastine
Sterptozocin	Vincristine
Carboplatin	Vindesine
Cisplatin	Vinflunine
Fluorouracil	
Methotrexate	
Temisirolimus	
Arsenic trioxide	
Bleomycin	
Cladrabine	
Cyclophosphamide	
Eribulin	
Monoclonal antibodies	
Penostatin	
Thiotepa	

6.5 Compartment Syndrome

Compartment syndrome can occur in any fascial compartment within the body. In the upper limb, any insult that results in tissue injury without a significant open fascial wound, such as crush injury, ischaemia or reperfusion, can cause a rise in compartment pressures. This pressure reduces venous return, increasing the pressure further. A vicious cycle is established which ultimately leads to tissue necrosis. Early implications of compartment syndrome are life-threatening rhabdomyolysis and acute kidney injury as a result of muscle breakdown. If surgical treatment is delayed, Volkmann ischaemia contractures will develop in the affected muscle groups in the future.

Due to the potential severity of compartment syndrome, accurate assessment is critical. Features to assess include:

Symptoms

- Numbness or paraesthesia
- Pain
- Stiffness

History

- The weight of crushing object
- Duration of the limb entrapment
- Any history of recent surgery to the limb, particularly orthopaedic with plaster casts in place

Examination

- Swollen, firm, tender compartments
- Severe pain, particularly on passive movement
- Paraesthesia
- Loss of peripheral pulses (a late sign)
- Dark urine secondary to rhabdomyolysis

Some units may have intra-compartment manometry pressure probes, which can be used as an adjunct to clinical diagnosis;

- 0–10 mmHg: normal
- 10–20 mmHg: high- suspect compartment syndrome
- >20 mmHg: abnormally high- compartment syndrome very likely and urgent fasciotomy required

Despite this, surgery for compartment syndrome should be based on clinical features and so if signs are present suggesting compartment syndrome, surgical release through fasciotomies must be arranged urgently. X-ray radiographs may reveal underlying fractures but the diagnosis and surgical management should not be delayed by awaiting imaging.

In the forearm, two incisions can release all of the compartments: one volar forearm incision and one dorsal. In compartment syndrome of the hand, there are ten compartments which must be released:

- Thenar
- Hypothenar
- Adductor pollicis
- Four Dorsal interossei
- Three Palmar interossei

Hand fasciotomies therefore require two dorsal longitudinal incisions over the second and fourth metacarpals to decompress the interossei, one volar longitudinal incision over the first metacarpal for the thenar compartment and one volar longitudinal incision over the fifth metacarpal for the hypothenar compartment. The carpal tunnel may also need to be decompressed.

Once the compartments have been released, the patient must be closely monitored and well hydrated, with urine output measured hourly. Skin grafting will inevitably be required for the fasciotomy wounds once the pressures have normalised.

6.6 Burns

Burns can be caused by a multitude of modalities including flame, friction, electricity, cold and chemicals. They are grouped together as management shares many similarities.

All patients must be clinically stabilised, with respect to their airway and haemodynamic parameters. Once stabilised, the burn itself can be assessed. It is important to calculate the burn size as a percentage of the total body percentage area (%TBSA), the depth of the burn and whether there are any circumferential burns.

The %TBSA can be estimated using the palm of the patient's hand as a guide to 1%TBSA, or by using a Lund and Browder chart. The depth of a burn is usually assessed according to clinical features (Table 6.2).

Burns resuscitation usually involves large volumes of intravenous fluid. Parkland's formula is the most appropriate way of calculating IV fluid volumes in the first 24 hours of burns resuscitation. Fluid resuscitation should be instigated

Table 6.2 Features of burns by depth

Depth	Appearance	Blisters	Pain	Scarring
Epidermal	Red, blanching	No blisters	Painful	Should heal without scar
Superficial dermal	Pale pink, blanching	Blisters	Very painful	Will heal with colour mismatch
Deep dermal	Dark pink, non-blanching (fixed staining)	No blisters	Usually insensate	Always scars
Full thickness	White, waxy, charred, non-blanching	No blisters	Insensate	Scars with contracture

in any burn of >10% TBSA burns in children and >20% TBSA burns in adults:

Parklands formula is: 2–4 ml × %TBSA × patient weight in kg = volume of fluid to be given in the first 24 hours from the time of injury, with the first half given in 8 hours, and the second half in the next 16 hours.

In smaller burns, blisters should be deroofed and dressed appropriately with non-adherent dressings.

Circumferential burns of the limbs may become constrictive and require urgent escharotomies to prevent the pressures rising within the limb and resulting in a vicious cycle similar to compartment syndrome. Escharotomies are usually performed in theatre. Due to the systemic effects of a burn, and the deep incisions required, there can be significant bleeding which must be effectively controlled.

A specific subset of chemical burn often seen in the hand is caused by hydrofluoric acid. This is found in some chemical cleaning products and glasswork materials, and so must be considered in anyone who presents with burns and a history of using these chemicals. Fluoride ions cause liquefative necrosis, propagating the spread of the chemical agent, as well as reacting with calcium and reducing serum calcium levels which can have cardiotoxic effects. Treatment is by irrigation, trimming or removing nails if the burn is on the fingertips, and topical or subcutaneous calcium injection. Intravenous calcium may be required in critical conditions. In practice, burns to the hand, those requiring escharotomies and chemical burns are subsets of burns that require specialist management and should always be discussed with a burns centre.

Chapter 7
Tendon Injuries

Ravina Tanna and Joanna Mennie

Tendon injuries should always be suspected in hand lacerations, particularly glass lacerations. In this chapter we will review the management of flexor and extensor tendon injuries.

Salient points from the history include patient hand dominance, smoking status, occupation, hobbies, past medical history, and mechanism of injury. A systematic examination of sensation, CRT, and the function of all FDS, FDP, and extensor tendons against resistance should be undertaken. Pain against resistance can often indicate a partial tendon laceration. The thumb examination should include flexion, extension, opposition, abduction and adduction.

Imaging should involve three view X-ray radiographs to assess for bony injury or foreign body.

7.1 Flexor Tendon Injuries

Initial management of a suspected flexor tendon injury in ED should involve; irrigation with saline, cleaning of contaminated wound with chlorhexidine or betadine, application of non-adherent dressings, oral antibiotics if infection is likely or

R. Tanna (✉) · J. Mennie
Department of Plastic Surgery, Royal Free Hospital, London, UK
e-mail: Ravina.tanna@nhs.net

P. Singh (ed.), *Hand Trauma in Clinical Practice*, In Clinical Practice, https://doi.org/10.1007/978-3-030-10844-1_7

open fracture present, tetanus Revaxis, and plaster of Paris. The patient should then be booked as per department policy for an operating list.

The patient should be consented for regional/general anaesthesia in suspected flexor tendon injuries as the proximal end may retract necessitating more proximal exploration into the palm, or even the carpal tunnel. Specific complications that should be discussed include tendon rupture, stiffness, reduced range of joint motion, need for hand therapy, and potential for future tenolysis surgery.

Patients should be prepped and draped in a standard fashion with the arm outstretched on an armboard and an arm tourniquet applied. A lead hand is also helpful. Wounds should be extended in either a Brunner, or mid lateral approach. The decision as to the incision approach is often pre-determined by the existing laceration.

The decision to repair a tendon depends on the extent of damage and delay to presentation.

If <50% of the tendon is lacerated it can be conservatively managed without repair. For acute presentations with >50% tendon lacerated, a primary repair is undertaken. This involves a core repair using an Adelaide, Cruciate, or Kessler approach (Fig. 7.1), with an epitendinous running continuous or Silverschiold suture (Fig. 7.2) which provides 25% of the primary repair. Core repair is often with 3/0 prolene, and epitendinous with 5/0 prolene. There is a balance between a strong repair and an excess amount of suture material in the tendon which can hinder healing and predispose to re-rupture. Studies have shown number of strands across the repair, and suture type to influence on strength of repair.

After surgery, the hand should be placed in a dorsal POP and a subsequent thermoplastic splint to protect the repair. Hand therapy will be required for 6–8 weeks post-operatively and during this time patients must take care to avoid heavy lifting or sport. This will have implications for driving (they should discuss their predicament with their insurance company), occupation and hobbies. Smoking is particularly damaging to tendon healing and cessation advice must be given.

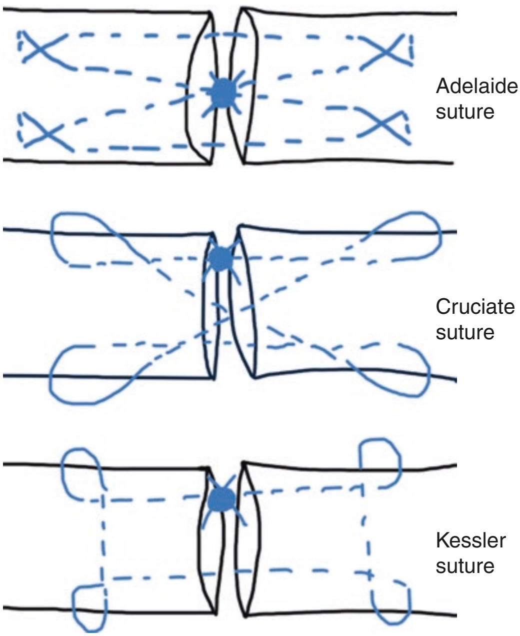

FIGURE 7.1 Core suture techniques; Adelaide, Cruciate or Kessler

If the tendon injury is more than 2 weeks old, it is likely that the proximal tendon will have retracted. A two-stage repair may be warranted if primary repair during initial exploration is not possible (Fig. 7.3). Patients with a delay to surgery should be consented for this potential eventuality. A two-stage repair involves;

Stage 1: the creation of a fibrous tunnel using a silicon rod sutured to the proximal and distal ends of the cut tendons, with maintenance of, or reconstruction of key flexor tendon pulleys. If there is no distal tendon to suture to, the silicon rod may be embedded in to the distal phalanx using an anchor or pulled through the tip of the finger and tied around a button.

Stage 2: A tendon graft using palmaris longus or plantaris tendon is taken and inset in to the fibrous tunnel, as the

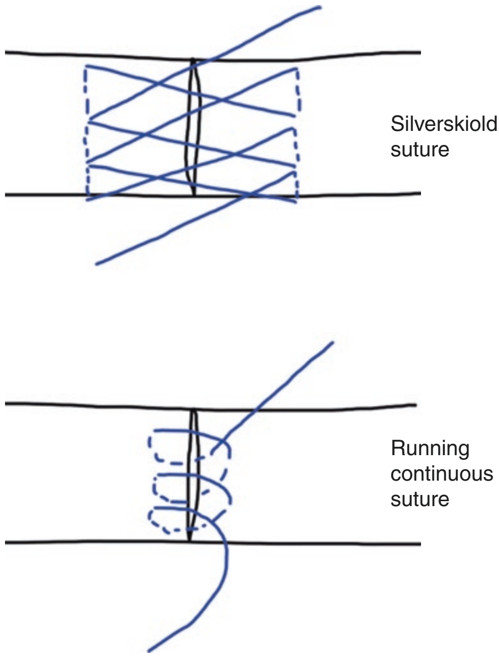

Figure 7.2 Epitendinous suture techniques; Silverskiold or running continuous

silicon rod is pulled out. Stage 2 is undertaken approximated 3 months after stage 1.

Extensive hand therapy is required for the two-stage repair and candidates must be well informed of the arduous journey ahead before undertaking this.

7.2 Extensor Tendon Injuries

As before, a thorough history and examination is required. EDC, EIP, EDM, EPL, EPB, APL, ECRL, ECRB and ECU should all be examined. The zone of injury should be identified and any additional damaged structures. An EUA with LA should be attempted after sensation is assessed.

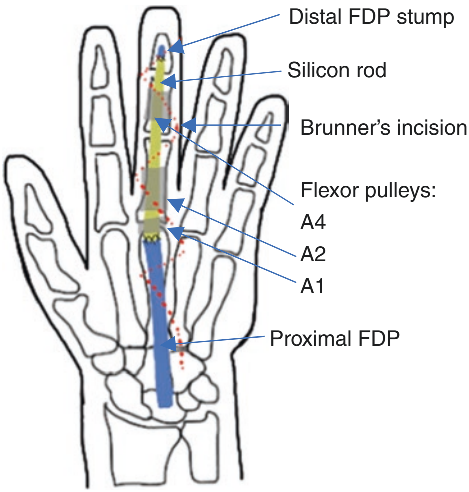

FIGURE 7.3 After the first stage of a two-stage flexor tendon reconstruction

Imaging and initial management is as before. Cut tendons need formal repair in theatre. Isolated extensor tendon injuries can be operated on under LA from zone 5 distal. Proximal to zone 5, extensor tendons can also retract when injured, and a general anaesthetic is more appropriate. Specific complications that should be discussed include tendon rupture, stiffness, reduced range of joint motion, need for hand therapy, and potential for future tenolysis surgery.

Surgery proceeds in the same fashion. For those injured proximal to zone 5 an arm tourniquet is required, for those distal a finger tourniquet is appropriate. Wounds should be extended in a 'lazy S' fashion where appropriate with consideration for potential proximal extension for retracted tendons. Planning incisions is particularly important for potential EPL injuries whereby the tendon path winds around the scaphoid towards its third extensor compartment.

If the tendon is large enough a Cruciate or modified Kessler repair can be undertaken. If the extensor tendon is

too thin and flat, horizontal mattress sutures can be used with 3/0 prolene. Alternatively a continuous interlocking mattress repair has been shown to spread the tension across the length of the repair and is a good option. A volar POP splint to prevent stretching of the extensor tendon repair when the hand flexes will then protect the repair before seen by hand therapy.

Again patients should refrain from heavy lifting or sport for 8 weeks following surgery. They will be provided with thermoplastic splint from hand therapists the week following surgery and begin early active protected mobilisation with weaning of splints around the 4–6 week mark.

Closed mallet injuries which are either non-bony, or bony but involving <50% of the articular surface and not subluxed, can be treated conservatively with the digit held in extension in a mallet splint for 8 weeks. If involving more than 50% of the articular surface or significantly displaced, an Ishiguro technique using two K-wires can be used. However, this technique has been associated with infection and fingertip loss, so should be reserved for severe cases.

Chapter 8
Locoregional Flaps in the Hand

Wojciech Konczalik, Dominika Michno, and Norbert Kang

8.1 Introduction

Complex hand injuries are frequently associated with loss of skin and soft-tissue resulting in defects exposing the neurovascular bundles, tendons or bone that are not amenable to primary closure [1]. In these instances, the wounds may not support a skin graft and flap cover should be considered. Fortunately, there are a wide array of local flaps in the hand that can provide robust cover for small to medium-sized defects [2, 3]. A hand surgeon who possesses a good understanding of the vascular supply of the hand and the options for local flap cover should be able to manage the majority of defects encountered in a trauma setting. However, selection of the right reconstructive option is essential, based on a consideration of the size, composition and location of the defect, the presence of any vascular injury or comorbidities, combined with an assessment of the patient's pre-injury function and post-treatment goals. When considering flap cover, special consideration must be given to any pathology which can impair flap vascularity, especially; peripheral vascular disease, diabetes, smoking, sickle cell anaemia, polycythemia or vasculitis [4]. Previous injuries and/or surgery should be noted as well as hand dominance, occupation and hobbies, as all of these factors may

W. Konczalik (✉) · D. Michno · N. Kang
Department of Plastic Surgery, Royal Free Hospital, London, UK

P. Singh (ed.), *Hand Trauma in Clinical Practice*, In Clinical Practice, https://doi.org/10.1007/978-3-030-10844-1_8

influence the final choice of flap. The clinical examination should evaluate the dimensions, composition and location of the defect as well as the quality of the neighboring tissues and any potential donor sites [5]. The presence of any associated fractures, tendon and/or nerve deficits must be elicited before surgery as these may also affect the surgical plan and may even necessitate a multidisciplinary approach. It goes without saying that the operating surgeon must possess experience in reconstruction of the hand and be comfortable performing a variety of reconstructive procedures so as not to limit the surgical options available to the patient. In most cases, the simplest procedure that will provide adequate soft-tissue cover and maximum functional recovery with the smallest amount of donor site morbidity is always best.

8.2 Reconstruction of the Dorsal Side of the Hand

Small to moderate, soft-tissue defects of the dorsum of the hand can be reconstructed with random pattern flaps raised immediately superficial to the paratenon. Hatchet flaps, transposition flaps, rhomboid flaps as well as rotation flaps can be used to cover wounds overlying the dorsum of the metacarpals as far distal as the metacarpophalangeal joint. In 1990, Quaba and Davidson from Scotland introduced the distally based dorsal hand flap based on the recurrent cutaneous branch of the dorsal metacarpal artery (Fig. 8.1) [6]. It can be used to cover defects over the dorsum of the metacarpophalangeal joint, web space and dorsal phalangeal areas as far distal as the DIPJ. It may be designed on the second, third or fourth intermetacarpal spaces – depending on which dorsal metacarpal artery perforator is used. The flap is elliptical in shape with a width of up to 3.5 cm. The pivot point of the flap is located at the distal tip of the ellipse which coincides with the entry point for the perforator – 0.5–1 cm proximal to the adjacent MCPJ, in the intermetacarpal space. The flap is based on very fine vessels, which can make the dissection difficult. In particular, failure to include sufficient venous drainage can lead to problems with venous congestion after transfer of the

FIGURE 8.1 A Quaba flap was used to reconstruct a second web-space defect. A skin graft would have been a simpler and faster solution, but the case illustrates the rotation of the flap through 180° and the reach of the flap

skin paddle. To minimise the chance of iatrogenic damage, it is important to perform the dissection with the tourniquet inflated but without exsanguination of the limb. This facilitates identification of the vascular pedicle. The skin is incised on one side of the ellipse stopping at the paratenon. Undermining of the flap in this plane is performed until the pedicle is identified distal to the inter-tendinous connection of the extensor tendons. The arc of rotation is typically 180° and skin paddles as large as 27 cm^2 have been described, making the Quaba flap a useful option when faced with a wide variety of dorsal hand defects. However, it is important to remember that the dorsal skin of the hand is hair bearing and this may limit its use in web space or distal palmar reconstructions. Moreover, when the width of the skin paddle exceeds 2.5 cm, a skin graft is required to close the donor site. Healing of the donor site can then be problematic.

More substantial defects of the dorsum of the hand are usually resurfaced with non-meshed split thickness skin grafts (if a vascularized bed is present) or covered with regional/distant flaps. Unfortunately, the utility of skin grafts is limited in this area because of the effects of secondary contracture of the graft (Fig. 8.2), incomplete sensory recovery, recipient site sensitivity and poor cosmesis.

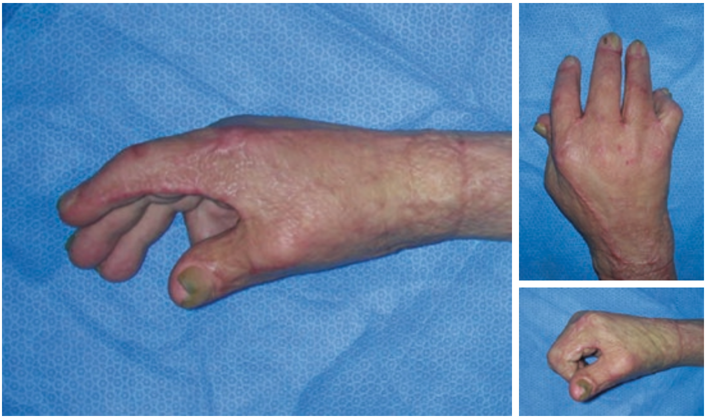

FIGURE 8.2 Split thickness skin graft on dorsum of hand at 18 months after burn injury showing web contractures at the edge of the graft and limited range of movement due to contraction of the graft

Many different pedicled flaps have been described for reconstruction of the dorsum of the hand. The list includes but is not limited to; the posterior interosseous flap, the radial and ulnar artery forearm flaps and the more recent introduction of both radial and ulnar artery perforator flaps (Figs. 8.3 and 8.4). More recently, dermal substitutes (e.g. Integra™, dCELL™, Alloderm™ or Matriderm™) have been shown to be a viable option for dorsal hand cover with aesthetic and functional outcomes superior to split thickness skin grafting alone whilst avoiding the donor site morbidity of a local flap.

Extensor tendon loss in cases of dorsal soft-tissue loss can be managed as a staged procedure with soft-tissue coverage first, followed by tendon transfer or grafting (Fig. 8.3). Alternatively, single-stage transfer using composite radial artery or dorsalis pedis flaps can be employed to provide skin cover and simultaneous transfer of tendon grafts (Fig. 8.5).

Injuries to the web spaces can be reconstructed using a variety of local and random pattern flaps combined with Z-plasty and V-Y advancement. When more skin is needed, a full thickness skin graft can be used to deepen a web space.

8.3 Reconstruction of the Palmar Side of the Hand

Palmar reconstruction poses unique challenges. The skin on the palmar side of the hand is designed to facilitate prehension while protecting vital structures. It is densely innervated, more so than the dorsum or forearm. Therefore, raising local flaps from the palmar skin can interfere greatly with sensation, leading to problems with anaesthesia, dysaesthesia or hyperaesthesia. In a worst-case scenario, patients may bypass the area resurfaced with a flap or graft since sensory feedback is either absent or (worse) very abnormal, rendering the affected digit or area of the hand unusable. Moreover, the palmar skin is thick, glabrous and fixed to the underlying palmar aponeurosis with multiple fibrous septae which limit the mobility of any local flaps. Disruption of the septae is essential to mobilise any flap. However, the septae do not reform after transfer of the flap. Instead, a layer of scar tissue

FIGURE 8.3 Dorsal skin loss due to circular saw injury. Debridement of wound and repair of multiple divided tendons. The dorsal wound was covered with a pedicled radial forearm flap with a full thickness skin graft applied to the donor defect. Final images at 4 months post-op

FIGURE 8.4 Skin loss over the dorsum of the hand after a burn and crush injury at work. This patient is clearly accident prone and had already sustained a previous terminalisation of his index and middle fingertips in a separate, work-related injury treated elsewhere. The fingertips were covered with a FTG. After debridement, there was exposure of the extensor tendons. Therefore, the dorsal wound was covered with a pedicled ulnar artery forearm flap with full-thickness skin graft applied to the donor defect

is formed between the flap and its recipient site and this can lead to problems with stability of the soft-tissue in the years after the transfer is performed. Finally, deep to the skin, there is a layer of adipose tissue of varying thickness which provides soft-tissue padding for the underlying neurovascular

FIGURE 8.5 A router injury to the dorsum of the left thumb over the metacarpophalangeal joint. There was partial loss of the MCP joint which was fractured and exposed, plus a segmental loss of the extensor mechanism. The wound was debrided and the MCP joint was arthrodesed acutely using a tension band wiring technique. The dorsal wound was covered with a pedicled radial forearm flap harvested together with a segment of the brachioradialis tendon for interposition reconstruction of the missing segment of the EPL tendon. The flap was tunneled through to the defect and inset

bundles and tendons but also has the potential to make any palmar flap more bulky.

To achieve optimal outcomes in the reconstruction of any palmar defect, the surgeon must select donor tissue which is robust but not bulky, has high pliability to avoid impairment of motion and is sensate. In many cases, small defects (typically <1–2 cm wide) on the palmar side of the hand can be left to heal by secondary intention – even when "vital" structures such as tendons and nerves are exposed (Fig. 8.6).

FIGURE 8.6 Two patients with exposed tendons and neurovascular bundles after percutaneous release of Dupuytren's cords. Left: Patient at 1-year post-op. Right: patient at 6 months post-op. It is critical to splint the fingers in extension (especially at night) while the fingers are healing to avoid developing a significant flexion deformity

Provided that any wound is dressed, and a moist healing environment is created, the glabrous skin exhibits excellent wound contraction properties and re-epithelialises quickly (typically within 2 weeks). Healing in this way results in a scar that rarely results in significant functional or cosmetic impairment. Importantly, the result is usually sensate. As an alternative, small split or full thickness skin grafts harvested from the hypothenar eminence or the plantar arch can be used to accelerate re-epithelialisation. However, the availability of such grafts is very limited and the main role of such an approach is to use the grafts as a biological dressing while the wounds heal (mostly) by secondary intention. Split thickness skin grafts should not be used to cover large palmar defects, since they are insensate and lead to problems with instability and breakdown in the long-term as well as creating the usual problems of scar contracture. Although full-thickness skin grafts do not have the same problems with palmar wound contraction, they are likewise insensate and are likely to be bypassed by the patient. Moreover, they are often hyperpigmented and result in significant cosmetic impairment as well as being potentially hairy – if care is not taken to remove every single hair follicle during harvest of the graft (Fig. 8.7). Removal of all the hair follicles is a particularly time-consuming but necessary process.

Figure 8.7 Left: Hairy FTGs (from groin) on fingers after Dupuytren's dermofasciectomy. Right: FTG (from groin) on hand after burn injury showing significant colour mismatch resulting in frequent and unwanted remarks about having "dirty" hands

Larger defects can be closed with reversed flow pedicled flaps based on the radial or ulnar artery, or more commonly, with free-tissue transfers. The only distant flap capable of introducing significant quantities of glabrous skin is the medial plantar flap and the dissection for this flap is difficult. However, there are many descriptions of other flaps which have been used to good effect in this area.

8.4 Reconstruction of the Digit

Soft-tissue injuries of the fingers are common. The dorsum of the digit has thin, pliable skin with minimal tendon excursion. Moreover, the density of sensory end-organs is less than on the palmar side and the need for a sensate reconstruction is therefore less compared to the palmar side. In contrast, the palmar side of the finger has glabrous skin similar in its properties to that of the palm of the hand with a high density of sensory end-organs. Therefore, sensate reconstruction of the palmar side of the digit is critical to ensure that the patient does not (ultimately) bypass a fully healed finger.

Dorsal digital defects are easily reconstructed with full thickness skin grafts, provided that the paratenon is preserved. Random pattern flaps such as hatchet or rotation flaps can also be used on the dorsum. These rely on recruitment of any skin laxity over the PIPJ and MCPJ. The Quaba flap, described previously, can also be used to resurface defects on the dorsum of the digit – extending up to as far as the DIPJ.

Patients who suffer an acute amputation of their digits should of course be offered the possibility of microvascular replantation, provided that there are no significant underlying co-morbidities. Amputation of the thumb is of course an absolute indication for replantation. However, not every patient is suitable for replantation and the facilities or the microsurgical skills necessary to make this a success are not always available. Therefore, composite grafting may be considered – for both children and adults – provided that the warm ischaemia time is <6 hours. To extend the utility of this

approach, especially in cases where the warm ischaemia time is >6 hours, we recommend wider use of a composite-flap approach.

A composite flap approach (Fig. 8.8) involves the use of a homodigital flap (e.g. V-Y, Venkataswami or Moberg) in combination with a small part of the amputated part (typically the nail complex, which is the hardest part to reconstruct). The flap provides a vascularised bed for the composite tissue and

Figure 8.8 Crush amputation in a door at 12 hours after injury. It was not possible to replant the part due to the nature of the injury. Therefore, a V-Y homodigital flap (Venkataswami type) was raised and advanced to the tip of the finger. Composite tissue was harvested from the amputated part and placed onto the volar flap. Because the amount of composite tissue used was small, it was more likely to survive. The parts which should be harvested should include the hyponychium because the transition from the nail bed to the pulp is difficult to reconstruct. Final appearance at 1-year post-op showing a slight, hook-nail deformity

makes it possible to discard most of the amputated tissues. Since the amount of non-vascularised tissue is small, the chance of it surviving is much higher than if the whole of the amputated part is simply sutured into place, in the hope that it will revascularize spontaneously. The cosmetic and functional outcome of such an approach is like that of a replanted digit for only a fraction of the complexity – especially for very distal amputations. Should these measures fail, terminalisation or later microsurgical reconstruction with a toe-to-hand transfer may be necessary.

For smaller (<1–2 cm), soft-tissue defects on the finger, local flaps can be used. However, satisfactory results can also be obtained when these small wounds are allowed to heal by secondary intention. This approach is best suited to fingertip amputations affecting the pulp and hyponychium with little bony exposure or nailbed loss, as well as small volar defects located more proximally in the digit – even when the tendons or neurovascular structures are exposed. However, patients must be advised that healing may then take some weeks and/or may result in some distortion in the final shape/volume of the pulp and/or nail complex once the finger has healed.

The tip of the finger is most commonly affected by trauma and most local flaps in the digit are designed to address defects in this area. Several general principles apply when managing fingertip injuries (i.e. those occurring distal to the insertion of the flexor digitorum profundus). Preservation of bony length is of paramount importance since length is proportional to function. This is closely followed in importance by the need to provide well-padded, sensate, glabrous skin over the pulp, followed by restoration of the nail bed complex and preservation of tendon attachments. There are numerous local flaps described to help achieve these aims and, with growing experience, each surgeon eventually develops a personal algorithm to guide their injury-specific treatment. For simplicity, the reconstructive options listed below have been categorized according to their design i.e. flaps harvested from the same digit vs flaps harvested from adjacent anatomical region. We have also included descriptions of notable historic flaps as well as more recent modifications of these flaps.

8.4.1 Homodigital Flaps in Fingertip Reconstruction

8.4.1.1 Palmar V-Y Flaps

The palmar V-Y flap is commonly referred to as the Atasoy-Kleinert flap. It was originally described by an Italian surgeon Ettore Tranquilli-Leali in 1935. However, it was later popularized by Atasoy and colleagues in 1970 [7, 8]. It is used for dorsal oblique and transverse amputations as well as volar oblique amputations where sufficient pulp is present for reconstruction (typically for angles of amputation not exceeding 30°). A different type of flap should be considered if the soft-tissue loss is predominantly volar. To provide adequate cover, the level of the amputation should not be more proximal than the middle of the sterile matrix. Importantly, this flap should be avoided in crush injuries since the dissection necessary to mobilise the flap increases the risk of soft-tissue necrosis.

The flap is designed as a "V" shape with the apex centered in the midline at the distal interphalangeal crease and the two limbs ending at the wound margin. The distal base of the flap is designed so that its width equals that of the nail. The skin incision along the limbs of the "V" should only penetrate through the skin, ensuring that the scalpel is withdrawn as soon as subcutaneous fat is visible. Tenotomy scissors are then used to gently spread the subcutaneous tissues and mobilise the flap to avoid damaging the terminal branches of the digital neurovascular bundles. The deep dissection proceeds from distal to proximal keeping close to the periosteum and flexor sheath whilst gently dividing the fibrous septae holding the pulp onto the bone, thereby allowing the flap to be mobilised. The tissues can then be advanced distally with skin hooks. The donor site is now closed in a V to Y fashion whilst the flap is kept under tension. This prevents the flap from migrating proximally, back into its former position. The flap is then secured to the wound margins with fine sutures taking care not to generate undue tension as this will impede

sensory recovery and may result in flap necrosis. Advantages of the flap include avoidance of a midline scar on the pulp, which may result in long-term hypersensitivity and pain, as well as the introduction of well padded, glabrous, sensate tissue to the fingertip. The clinical utility of the flap is limited by its small size and limited mobility. However, the latter is often the result of insufficient release of the fibrous septae holding the pulp tissues in place. Sensation is often reduced as flap advancement always involves an element of tension resulting in injury to the terminal branches of the digital nerves. A hook-nail deformity is a common complication which results from use of the flap in fingertip injuries which are too proximal or too volar.

The Atasoy-Kleinert flap was later modified by Elliot et al. in 1995 who described a more useful, neurovascular palmar V-Y flap [9]. Elliot's flap is based on the digital neurovascular bundles rather than their terminal divisions in the pulp. The modifications made it possible to design a flap which is considerably larger and places the apex of the "V" more proximally over the middle of the middle phalanx. The larger flap makes it possible to cover fingertip amputations at the level of the eponychial fold and it can readily cope with volar oblique amputations with a slope of up to 35°. Because it is raised on the digital neurovascular bundles, the flap can be designed at any point along the digit and can be used to cover the stump in amputations as proximal as the proximal phalanx. However, it is important to design the limbs of the "V" so that they cross the skin creases obliquely, to minimise the risk of volar web contracture. Raising the flap is similar to that performed for the smaller, original, palmar V-Y flap. However, the aim is to visualize the neurovascular bundles coming into the underside of the flap during deep dissection and to include them in the tissue that is mobilised. When used for fingertip reconstruction, it is also necessary to trim the leading edge of the flap to match a normal fingertip. Otherwise, the final outcome can have an unnatural, rectangular appearance.

8.4.1.2 Lateral V-Y Advancement Flaps

There are several variants of the lateral V-Y advancement flap for fingertip reconstruction. All of the flaps are based on a single digital neurovascular bundle and are designed as a non-equilateral triangle with the short limb of the V corresponding to the mid-lateral line and the long limb terminating at the wound edge at the midline of the digit. Depending on which variant is used and whether the flap is raised in a unilateral or bilateral fashion, lateral V-Y homodigital flaps can be used to resurface a variety of fingertip defects by advancing sensate glabrous tissue to the tip of the finger.

The first description of a lateral V-Y flap in the finger was by Geissendörfer in 1943. He described the use of a unilateral V-Y flap commencing at the DIPJ to resurface a small, fingertip defect [10]. The dissection was similar to that described for the Atasoy-Kleinert flap with advancement of the tissue obtained by releasing the deep fibrous septae of the pulp without skeletonizing the neurovascular bundles. This flap is only suitable for covering very small defects and is not used routinely in clinical practice. In 1947, Kutler and his colleagues described the bilateral variant of Geissendörfer's flap [11]. Kutler described using two triangular flaps with one limb of the “V” lying along the mid-lateral line and the second limb terminating at the midline of the pulp distally. Kutler flaps have very limited clinical value because of their small size and negligible advancement. They also result in a midline scar on the pulp which may become problematic.

The more useful, lateral, homodigital, V-Y flaps are the Segmüller and Lanzetta flaps (Fig. 8.8). Both harvest large skin paddles proximal to the DIPJ and are pedicled on the digital neurovascular bundles to allow for greater advancement [12, 13]. The former was first reported in 1976 and involves harvesting tissue from the lateral sides of the digit with the tip of the V designed as proximal as the PIPJ crease. Classically, it is used in transverse fingertip amputations as proximal as the DIP joint. However, it can also be used for reconstruction of any volar sloping defect greater than 35°.

The Segmüller flap is raised as either a unilateral or bilateral neurovascular flap (i.e. raising two flaps from each side of the finger). In contrast, the Lanzetta flap, also known as the extended Segmüller flap, is extended even further by placing its apex over the middle of the proximal phalanx. As it is larger than all the other lateral V-Y flaps, it can be raised as a unipedicled flap whilst avoiding a problematic midline scar (Fig. 8.9).

Dissection of both flaps commences by making an incision down to the periosteum in the mid-lateral line. To allow the tissue to advance, Cleland's ligaments must be divided completely. The skin overlying the medial limb of the flap is now incised and the subcutaneous tissue gently spread with dissection scissors. Supra-periosteal dissection can then commence, both proximally and distally, once the neurovascular bundle has been visualized on the deep surface of the flap. Small vascular branches to the flexor tendon must be divided at this stage. Further advancement of the flaps can be gained by extending the mid-lateral incisions more proximally and mobilizing the neurovascular bundles to allow them to lie more centrally. Care must also be taken not to injure the small veni comitantes and veins present in the subcutaneous tissues surrounding the digital artery and nerve since this might lead to venous congestion after transfer to the recipient site.

8.4.1.3 Venkatswami Flap (Figs. 8.8 and 8.10)

This oblique triangular flap was originally described by Venkataswami and Subramanian in 1980 [14]. It is best used for large, volar-oblique defects with slopes greater than 30° and much like the flaps described above, it relies on a V-Y design. It differs from the lateral flaps in that the medial limb of the "V" is designed so that it crosses the midline of the digit and terminates at the contralateral wound margin. As a result, any tissue harvested from the advancing contralateral edge of the flap is insensate and is reliant on a random pattern vascular supply. Secondly, it can only be raised as a

FIGURE 8.9 Crush amputation of the radial border of the middle fingertip with a punch tool. The defect reconstructed with a single Segmüller-type, lateral V-Y islanded flap. The neurovascular bundle has been mobilised by extending the mid-lateral incision proximally, to divide small vessels and nerve branches. Appearance of the finger at 7 days post-op

Figure 8.10 Flap laceration to the pulp of the right little finger followed by pulp necrosis. After debridement, the fingertip was contracted and insensate with just a thin layer of epidermis on bone. A decision was made to resurface the tip with a Venkataswami type V-Y flap, islanded on an ulnar, neurovascular pedicle and advanced to the tip of the finger. Flexion of the IP joints was needed to achieve full "advancement" of the flap

unilateral flap. Nevertheless, this does not reduce its clinical utility as it permits the mobilisation of an even larger skin paddle than its lateral V-Y counterparts and partially obviates any concerns over midline scars of the pulp by placing the scar obliquely. If the quality of the donor site tissues permits, the flap should be harvested from the ulnar side of the finger in all digits except the little finger, to minimise any sensory impairment. The apex of the triangular flap is usually located at the PIPJ flexion crease and if more tissue is needed, the flap can be extended to the base of the digit.

Dissection of the Venkataswami flap is similar to that described for the Segmüller or Lanzetta flaps. However, it is

important to commence the deep dissection on the contralateral distal margin and to identify any contralateral digital vessels to ensure that they are not accidentally included in the flap. The ipsilateral neurovascular bundle is mobilised as far proximally as the MCPJ to aid in flap advancement. In this way, it is possible to advance the flap by as much as 2 cm. Because a large skin paddle is raised, use of the Venkataswami flap can result in an “hour-glass” constriction of the digit. Moreover, part of the “advancement” often comes from slight flexion of the interphalangeal joints. Therefore, patients may experience some loss of extension, once healing is complete. To avoid this outcome, it is necessary to ensure that intensive hand therapy and splintage are employed, once the flap is secure and seen to be viable. Stretching out of the finger can begin as early as 1 week after inset without compromising the vascularity of the skin paddle.

A modification of the Venkatswami flap was suggested by Evans and Martin in 1988. They recommended altering the design of the skin paddle by creating a step-pattern along the medial incision instead of the traditional straight line [15]. The rationale behind the stepped incision is that it minimises the risk of scar contracture and prevents retraction of the skin paddle. The downside of this modification is the necessity for significant surgical experience to design the unusual incision, making an already complex procedure even more complicated.

8.4.1.4 Reverse Homodigital Island Flap

Originally described by Lai in 1989, this flap relies on the retrograde flow through the digital artery which occurs through an anastomosis with the contralateral vessel on the volar surface of the DIPJ at the level of the vinculae [16]. It differs from all the previous reconstructive options for fingertip reconstruction in that it does not rely on a V-Y advancement. Instead, a paddle of skin (up to 2.0 × 1.5 cm) can be raised, centered over the junction between the volar (gla-

brous) and dorsal (hair bearing) skin at the level of the middle of the proximal phalanx. The skin paddle is islanded on its vascular pedicle and transposed onto the fingertip wound. The donor site is normally grafted as the defect (unless very small) can rarely be closed primarily.

When dissecting the flap, identification of the digital nerve allows for preservation of the plexus of small veins in a 2–4 mm cuff of subcutaneous tissue surrounding the artery. The digital artery is ligated proximally, and a mid-lateral incision is extended distally, in the direction of the fingertip, to allow the pedicle to be mobilised. The arc of rotation is centered on the DIPJ, giving the flap a wide reach in a variety of clinical situations. It is important to inset the flap loosely and to avoid a tight closure of the mid-lateral, especially distally as this can result in vascular (mainly venous) compromise of the flap. The mobilised tissue is usually insensate but it is possible to neurotise the flap by including the dorsal branch of the digital nerve into the skin paddle. The other disadvantage of this flap is the need to sacrifice one of the digital arteries.

A modification of this approach can be used in the thumb, where the dorsal digital arteries are well developed. Therefore, it is possible to use the reverse flow principle, without needing to sacrifice a major digital vessel. The dorso-ulnar flap of Brunelli takes tissue from the first webspace which is supplied by the dorsal ulnar vessels by retrograde flow from the perforators around the IP joint of the thumb [17, 18]. A fairly large skin paddle can be raised which reaches the tip of the thumb and is particularly useful for resurfacing dorsal defects around the nail complex or to replace the nail complex itself when this has been removed completely, leaving bare bone. The main advantages of this approach include:

1. Avoids sacrificing a major digital vessel
2. Simple dissection
3. Possibility of closing the donor defect directly (Fig. 8.11 and Table 8.1)

Figure 8.11 Patient with chronic paronychia of the right thumb. A decision was made to perform a total nailbed ablation down to the bone. Therefore, there was a need for flap cover in the absence of a graftable bed. A dorsal ulnar artery flap (after Brunelli) was raised from the first webspace. The flap was transposed onto the dorsum of the thumb and the donor site was closed directly. Appearance at 9 months post-op

8.4.2 Heterodigital Flaps in Finger Reconstruction

8.4.2.1 Cross-Finger Flap (Fig. 8.12)

The cross-finger flap was originally reported by Cronin in 1951 who used this flap to manage finger injuries sustained by

soldiers in World War II [19]. Due to poor data dissemination, this flap was "re-invented" and popularized in 1950 by Gudin and Pangman [20]. The cross-finger flap is a random-pattern, cutaneous flap supplied by the dorsal branches of the digital artery. It is best used for large, volar oblique defects of the fingertip as well as any defects of the volar aspect of the finger which are too large to be resurfaced with a homodigital artery island flap.

The cross-finger flap is very robust and is particularly useful in patients who are smokers or those who are known to suffer from small vessel disease in whom an islanded flap would be at high risk of necrosis. The main disadvantage is that it is a staged procedure requiring immobilisation of two fingers for at least two (sometimes longer) weeks. This means that it is relatively contraindicated in the elderly who are less able to tolerate holding a fixed position for a prolonged period without developing significant long-term stiffness. As a random-pattern flap, it is constrained by the usual length:breadth ratio of 1:1. This makes it a good solution for large volar defects which span the length of more than one and a half phalangeal segments. However, it should be avoided for smaller defects which result in the creation of a flap with a relatively narrow base which may then compromise the viability of the tip of transposed tissue. Many of these smaller volar defects can probably be left to heal by secondary intention anyway, without needing to use a flap or graft (see above).

The cross-finger flap is usually designed as a rectangle over the entire dorsum of the middle and/or proximal phalanx extending from one mid-lateral line to the other. To raise the flap, an incision is made down to the paratenon on three sides of the flap: proximal, distal and distant to the recipient site on the donor finger. Undermining of the flap proceeds from the free corners of the flap down to the base of the rectangle in a plane immediately superficial to the paratenon. This creates a rectangular flap of skin which can be transposed to fit a defect on the volar side of the recipient finger. To extend the reach of the flap, Cleland's ligaments on the

TABLE 8.1 Overview of homodigital flaps

Flap	First described	Design	Vascular supply	Neural supply	Indications	Advantages	Limitations
Palmar V-Y flaps							
Palmar V-Y	*Tranqulli-Leali (1935)* [7]; *Atasoy et al. (1970)* [8]	V shaped flap designed from midlateral line to midline with apex at the DIPJ.	Terminal branches of digital artery.	Terminal branches of digital nerves.	Dorsal oblique and transverse fingertip amputation. Ideally less than $1cm^2$.	Sensate. Glabrous skin. No midline scar.	Limited advancement. Can result in hook nail deformity.
Neurovascular palmar V-Y	*Elliot et al. (1995)* [9]	V shaped flap designed from midlateral line to midline with apex at the DIPJ.	Ulnar and radial digital artery.	Ulnar and radial digital nerve.	As above but amputation site can be more proximal than the mid-nail fold.	More advancement than conventional palmar V-Y flap.	Higher risk for neurovascular bundle injury.
Lateral V-Y flaps							
Kutler flap	*Kutler (1947)* [11]	V shaped flap designed from midlateral line to midline with apex at the DIPJ.	Terminal branches of digital artery.	Terminal branches of digital nerves.	This flap is rarely used due to its negligible advancement.	Easy dissection with low risk of flap devascularisation. Glabrous skin.	Midline scar. Negligible advancement – this flap is less mobile than the palmar V-Y flap and as such is rarely used.

Segmüller flap	*Segmüller (1976)* [12]	V shaped flap designed from midlateral line to midline with at the mid-point of the middle phalanx.	Digital artery.	Digital nerve.	Volar sloping amputations of the fingertip with angle greater than 30°.	More advancement than Kutler V-Y flap. Can provide cover for substantial fingertip soft tissue defects especially if raised bilaterally.	Midline fingertip scar if bilateral.
Extended Segmüller flap	*Lanzetta and St-Laurent. (1996)* [13]	V shaped flap designed from midlateral line to midline with apex at the PIPJ.	Digital artery.	Digital nerve.	As above, however this variant is more suitable for larger defects.	Larger flap with greater mobility than the standard Segmüller flap. Unilateral flap coverage avoids midline scar.	More extensive soft tissue dissection than standard Segmüller flap.

(continued)

TABLE 8.1 (continued)

Flap	First described	Design	Vascular supply	Neural supply	Indications	Advantages	Limitations
Others							
Venkatswami flap	*Venkataswami and Subramanian (1980)* [14]	V shaped flap designed from midlateral line to contralateral wound edge with apex at the PIPJ.	Digital artery	Digital nerve	Dorsal and volar oblique fingertip amputations with angle greater than 30°.	Large, mobile flap comprised of sensate glabrous skin. Its design avoids midline scar formation in the fingertip.	Advancing edge of the flap is insensate and has higher potential for tissue necrosis. Medial limb of the flap creates longitudinal scar on the finger and can predispose to scar contracture. Relatively complex dissection.
Reverse homodigital island flap	*Lai CS et al. (1989)* [16]	2.0 × 1.5 cm skin paddle centered around digital artery proximal to the PIPJ.	Digital artery (reverse flow through communicating vessel at volar DIPJ from contralateral digital artery)	Insensate unless dorsal branch of digital nerve incorporated into flap.	Dorsal and volar oblique fingertip amputations.	Good for coverage of moderate defects of both the fingertip and the dorsum of the finger.	Insensate. Skin is not glabrous. Sacrifices digital artery. Need for skin grafting at donor site. Donor site hypersensitivity.

FIGURE 8.12 A patient with a flexor sheath infection of little finger. He sustained necrosis of the volar skin with exposure of the flexor sheath and tendon. A large cross-finger flap was raised from the dorsum of the ring finger and transposed over the volar aspect of the little finger. A FTG was applied to the dorsum of the ring finger and quilted with 5/0 vicryl rapide to stabilize the graft, thereby avoiding the need for a tie-over dressing. Appearance of the fingers at 4 weeks post-op, prior to division of the flap pedicle. Final three images – appearances at 4 months post-op with recovery of most of his finger flexion and showing the FTG settling in over the dorsum of the ring finger

side adjacent to the defect should be divided, taking care not to injure the neurovascular bundle on the donor finger.

The donor site is then resurfaced with a split or full thickness skin graft and the two digits are immobilised in a splint or with Kirschner wires (if it is anticipated that patient compliance with immobilisation is likely to be poor). K-wires are

particularly invasive and syndactylising the tips of the fingers with a 3/0 Prolene or 3/0 nylon suture passed through the nail plate is a better alternative for ensuring the fingers stay joined together for the requisite period.

After a period of 2–4 weeks, the pedicle is divided, and the two fingers are released. The flap can then be inset properly into both the recipient and the donor site. This technique does not allow for the transfer of sensate, glabrous skin and is therefore not a first-line solution for fingertip reconstruction. However, for larger defects on the proximal part of the finger, it is a very reasonable option. The main disadvantages are; the need for a skin graft on the dorsum of the donor finger, the lack of sensation in the transferred tissue and the need for prolonged immobilisation leading to stiffness. The donor site graft can often be a cause for functional and aesthetic impairment.

8.4.2.2 The Reversed Cross-Finger Flap (Fig. 8.13)

This flap is a modification of the cross-finger flap and was designed specifically to resurface defects on the dorsum of the finger. It was first used in 1982 by Atasoy who resurfaced a dorsal digital defect by transposing heterodigital adipofascial flaps harvested from the dorsum of the adjacent finger in order to create a graftable wound bed [21].

To raise this clever modification of the original cross-finger flap, the incisions are planned so that the flap of skin opens away from the anticipated recipient site (as opposed to the cross-finger flap where the skin flap folds out towards the wound). The skin flap is raised as a skin/dermis-only flap, leaving both the paratenon and subcutaneous tissue behind. It is this adipofascial subcutis which is then raised as a rectangular flap with the pedicle on the side towards the defect. The flap is then transposed to cover the wound on the dorsum of the recipient finger. The skin-only flap is then replaced to cover the donor site defect and a full thickness skin graft is placed over the adipofascial flap to complete the reconstruction. After 2–4 weeks, the pedicle is divided and mobilisation of the fingers can commence.

FIGURE 8.13 Defect over the dorsum of the left little finger after a planing (carpentry) injury. The extensor mechanism was exposed and the paratenon stripped away, resulting in a non-graftable bed. A reversed cross-finger flap was designed over the dorsum of the adjacent ring finger. A skin-dermis flap was raised on a radial pedicle to expose the underlying adipofascial layer. An adipofascial flap was raised on an ulnar pedicle, exposing the underlying paratenon and tendon of the ring finger. The flap was inset over the little finger and a FTG was applied over the flap. The appearance at 4 weeks post-op showing the syndactylising sutures. The flap was then divided under local anaesthetic

8.4.2.3 Thenar Flap

The thenar flap is a distant, random-pattern flap which was first described in 1926 by Gatewood [22]. It has since undergone multiple modifications to minimise the donor site morbidity. As a result of improvements in surgical technique and a better understanding of the vascular anatomy of the hand, the thenar flap is almost never used since there are now many, better, alternatives.

The main indication for this flap is for fingertip defects >1.5 cm^2 in children and young adults who are able to recover from the lengthy immobilisation of the digit necessary for the

thenar flap to work. It should only be used for patients who can flex their fingers so that the defect touches the thenar eminence without pain or discomfort, making it an option primarily for index and middle finger reconstructions. Because the skin of the thenar eminence is relatively thin, the thenar flap should not be used in manual labourers who require a thicker layer of soft-tissue cover to allow them to return to their pre-injury function.

We recommend the use of a "U" shaped flap designed with the base of the flap located within the mid-palmar skin crease as this maximizes the chance of primary closure of the donor site and (possibly) reduces the risk of scar hypersensitivity. It should be designed at least 50% wider and 30% longer than the defect. Dissection proceeds from the distal aspect to the flap base incorporating a generous cuff of subcutaneous tissue into the flap. The flap is inset into the wound and the finger is dressed in the maximum extension that the flap will allow. A single large stitch can be placed between the finger and the palm to ensure that the flap will not be avulsed. The most commonly encountered complication with this reconstruction (apart from stiffness of the digit) is a painful donor site scar. Furthermore, having the finger flexed into the palm for a long period results in difficulties with hygiene and predisposes to maceration of the skin and infection of the flap and the final reconstruction is of course insensate. Given these shortcomings, the thenar flap has long been superseded by V-Y advancement homodigital flaps and other options for fingertip reconstruction. However, it is a common examination question and it is therefore worth knowing something about it.

8.4.2.4 Flag Flap

This axial pattern fasciocutaneous flap was described independently in 1973, by two surgeons, Iselin and Vilain [23, 24]. It is supplied by a continuation of the dorsal metacarpal artery, distal to its anastomosis with the palmar vessels. The anastomosis is located at the level of the metacarpal neck.

The index and middle fingers are most commonly used as a donor site since the dorsal vessels are large in these digits. A nerve supply can be included which comes from the terminal branches of the dorsal ulnar or radial nerves – depending on the digit. The skin paddle is outlined over the dorsum of the proximal phalanx as a rectangular flap which extends from both mid-lateral lines and whose distal and proximal extent lies between the PIP and MCP joints. The lateral edges of the skin paddle of the flag flap are generally one third longer than its width and extend from its distal edge to the base of the web space resulting in the classic flag-like appearance once raised on its subcutaneous pedicle.

The flap is raised from distal to proximal, dissecting immediately superficial to the paratenon. It is not necessary to visualize the neurovascular pedicle and attempts to identify and skeletonize the vessels should be avoided as this can result in iatrogenic injury. Once raised, the flap can be rotated on a pivot point which is (generally) located at the base of the webspace. The flap can then be used to cover defects overlying the adjacent proximal phalanx (both dorsum and volar surface) as well as the adjacent web space and metacarpophalangeal joints. The donor site is resurfaced with a full thickness graft.

Nowadays, the flag flap is rarely used because of its limited reach and because it often results in problems with donor site hypersensitivity. Moreover, the vascular pedicle of this flap is often injured in traumatic injuries of the proximal digit and webspace, making other reconstructive options more suitable.

8.5 Reconstruction of the Thumb

The thumb is the single most important digit in the hand. Therefore, any tissue loss should be managed aggressively to preserve both length and function. In the case of amputations of the thumb, the patient should always be evaluated for a microvascular replantation, especially if the injury has

resulted in a clean (guillotine) amputation with no crushing or avulsion of the neurovascular structures.

Homodigital, V-Y advancement flaps such as the Tranquili-Leali, Segmüller and Venkataswami flaps can be used for small (1–2 cm^2) soft-tissue defects at the tip of the thumb. However, these flaps are not as effective in achieving cover compared with similar defects of the fingertips since the thumb is wider and shorter [7, 12, 14]. For this reason, several flaps have been designed, specifically for reconstruction of thumb defects which make use of the differences in the vascular anatomy of the thumb.

8.5.1 Moberg Flap (Fig. 8.14)

This volar advancement flap was first described by Moberg in 1964 [25]. It is raised on both volar, neurovascular bundles of the thumb. It is classically used for transverse or volar oblique amputations of the tip of the thumb where the tissues need to be advanced by <2 cm. To allow the pulp to be reshaped correctly, it is important to flex the interphalangeal joint when insetting the flap and to maintain this position for up to 2 weeks post-operatively. The Moberg flap is relatively contraindicated in the fingers as their dorsal blood supply is not as reliable and use of this flap is associated with dorsal skin necrosis. The flap is designed so that the lateral edges correspond to the mid-lateral lines of the thumb and the distal edge terminates at the margins of the defect. There are several modifications of the proximal aspect of the flap:

(a) **O'Brien modification:** the flap ends in a transverse line overlying the MCPJ crease of the thumb. The flap is advanced to the tip of the thumb and the flexor sheath/neurovascular bundles are skeletonised and exposed. The donor-site defect is then covered with a full thickness skin graft [26].
(b) **Foucher modification:** The flap is advanced as previously described and the proximal donor site defect is closed

FIGURE 8.14 V-Y modification of Moberg flap. Patient with partial amputation of tip of thumb – attempted reconstruction with a composite graft failed leaving exposed bone. Reconstruction with Moberg flap. Flap advanced to the tip of the thumb. Notice the slight flexion of the IP joint needed to achieve the advancement. Appearance at 6 weeks post-op

with a triangular transposition flap based on the ulnar border of the thumb [27].

(c) **V-Y modification:** This is the most common method for dealing with the proximal end of the Moberg flap. The base of the flap is extended 2 cm proximal to the MCPJ crease and tapered to a V over the thenar eminence. Once the flap has been advanced, the donor site can be closed in a V-Y fashion.

Raising the flap proceeds in a manner similar to that for the homodigital V-Y flaps previously described. The flap is lifted away from the periosteum and flexor sheath from distal to proximal. When the flap is extended to the level of the hypothenar eminence (as for a V-Y modification), the tissues are dissected at the level of the thenar musculature. The most common problem encountered with this flap is its lack of advancement. Much of the "advancement" is the result of

interphalangeal joint flexion and not actual advancement of the flap [28].

8.5.2 Kite Flap (Fig. 8.15)

The original description of the Kite flap was by Holevich in 1971 [29]. He described a flap based on the first dorsal metacarpal artery, with the skin paddle drawn over the dorsum of the index finger extending over the MCPJ and up to the proximal phalanx of the index finger. Holevich incorporated a long cutaneous tail which followed the course of the first dorsal metacarpal artery which lies along the radial aspect of the second metacarpal to its origin in the anatomical snuffbox – the pivot point of the flap. The incorporation of skin over the pedicle minimised the risk of torsion and compression of the vessel when the flap was transferred to the thumb. Foucher modified this flap in 1979 by removing the cutaneous tail and isolating the proximal part of the donor vessel in adipofascial tissue only, thereby creating a true island flap [30]. This made it possible to tunnel the flap from its donor site to the thumb.

The skin paddle can be raised more distally than in the original description by Holevich, commencing on the radial side of the metacarpal head and extending up to the level of the proximal interphalangeal joint, thereby allowing for coverage of more distal thumb defects. The flap is usually designed to be sensate and includes terminal branches of the superficial radial nerve.

Dissection commences distally, raising the flap at the level of the paratenon up to the level of the MCPJ. Proximal to this, a generous cuff of adipofascial tissue must be raised off the dorsal interosseous muscle to ensure that the first dorsal metacarpal artery is included in the flap. It is important to recognize that this vessel often runs deep to the fascia of the interosseous muscle and may take an intra-muscular course. Therefore, this tissue and the periosteum must sometimes be dissected free, down to the level of the radial artery at the

FIGURE 8.15 Kite flap used to resurface a volar defect on the right thumb. Flap marked out over the dorsum of the index finger with a long tail over the dorsal metacarpal artery. Part of the dissection is intra-muscular to ensure that the vessel is included in the flap. The flap is then inset into the thumb defect and a large FTG is placed over the donor site. The flap is seen to be very hairy and is of course insensate unless a specific attempt has been made to include branches of the superficial branch of the radial nerve. This patient would have been better served with a Moberg-or Venkataswami type homodigital advancement flap. The distal part of the thumb pulp was perfused by the robust dorsal circulation and would have easily survived when the Moberg flap was raised

base of the first ray. Although it is not necessary to visualize the artery, it is advisable to create a bridge of adipofascial tissue that is similar in width to the flap base to ensure that the vessels (artery and veins) and nerves are incorporated into the flap. It can also be helpful to perform a pre-operative Doppler to mark out the course of the dorsal metacarpal artery.

The kite flap is typically used for volar oblique fingertip defects of the thumb which are too large to be easily covered by a Moberg flap. It can also be used to cover wounds overlying the dorsum of the thumb, particularly when tendon and/or bone exposure is present. However, there are many limitations of the flap which the surgeon should be aware of:

1. It results in a cosmetically unfavourable donor site which requires a skin graft for cover. The resulting donor scar may become hypersensitive, especially if terminal branches of the superficial radial nerve are taken with the flap.
2. Unless the flap is designed with its distal margin at the level of the PIPJ of the index finger, it will not reach past the interphalangeal joint of the thumb.
3. The flap does not provide glabrous skin. Worse, it is often grossly hairy (especially in male patients) resulting in a hairy thumb which is unsightly and hard to maintain.
4. It does not reproduce the stability and bulk of the thumb pulp. This may lead to problems with absence of padding over the bone and soft-tissue instability when trying to perform tasks such as precision pinch or key pinch.
5. Although it can be made sensate, sensation in the flap is not normal. Therefore, patients may bypass the reconstructed tissues and avoid using the thumb. To address this, it may be necessary to perform a neurorrhaphy between the radial nerve branches included in the flap and the proper digital nerves of the thumb. This is usually best done at the time of transfer of the flap (Table 8.2).

8.6 Regional Flaps

Large soft-tissue defects in the hand cannot be closed easily with local flaps. This is particularly true if the soft-tissue defect is in the palm or dorsum of the hand. In such instances, coverage with regional or distant flaps should be contemplated. There is a vast list of distant flaps which can be used for this purpose and these can be designed to reconstruct composite defects including skin, tendon, nerve, blood vessel

Table 8.2 Overview of heterodigital flaps

Flap	First Described	Design	Vascular Supply	Neural Supply	Indications	Advantages	Limitations
Thenar flap	*Gatewood (1926)* [22]	Multiple designs – from rectangular to "U" or "H" shaped. Skin paddle centered on thenar crease/thenar eminence. Must be designed approximately 50% larger than fingertip defect.	Random pattern supply.	Insensate.	Transverse or volar sloping fingertip defects up to 1.5 cm^2	Glabrous skin. Elastic skin allows for primary closure of donor site.	Staged procedure. Can only be done in young individuals. Finger stiffness needs rehabilitation to minimise PIPJ contracture. Donor site scar hypersensitivity is common.

(continued)

TABLE 8.2 (continued)

Flap	First Described	Design	Vascular Supply	Neural Supply	Indications	Advantages	Limitations
Cross finger flap	*Cronin (1951)* [19]	Rectangular cutaneous flap designed over the dorsum of the middle and/or proximal phalanx.	Random pattern supply.	Usually insensate. Can incorporate dorsal branch of digital nerve.	Defects of the volar finger too large for coverage with homodigital island flaps. Patients with small vessel disease.	Robust cover in larger defects of the volar digit. Can be employed in smokers or patients with small vessel disease.	Staged procedure. Does not introduce glabrous skin. Contraindicated in older patients due to risk of joint stiffness. Need for skin grafting of the donor site.

Reverse cross finger flap	*Atasoy (1982)* [21]	Rectangular adipofascial flap designed over the dorsum of the middle and/ or proximal phalanx.	Random pattern supply.	Insensate.	Defects of the dorsum of the digit not amenable to skin grafting or reconstruction with homodigital random pattern flaps.	Adipofascial flap creates a graftable wound bed on defects of the dorsum of the digit that would otherwise need complex reconstruction.	As above. The adipofascial flap also needs a skin graft to complete reconstruction.

(continued)

Table 8.2 (continued)

Flap	First Described	Design	Vascular Supply	Neural Supply	Indications	Advantages	Limitations
Flag flap	*Iselin (1973)* [23]; *Vilain and Dupuis (1973)* [24]	Rectangular cutaneous flap designed over the dorsum of the proximal phalanx with skin paddle 1/3 width of flap extending from lateral edge of flap proximally into the webspace.	Dorsal metacarpal artery.	Terminal divisions of dorsal branches of the radial or ulnar nerve.	Defects over dorsum and volar surface of proximal phalanx of adjacent digit. Defects in the neighbouring web space or MCPJ dorsum.	Good for wounds exposing extensor tendon over the proximal phalanx of adjacent digit.	Arc of rotation limits reach. Need for skin graft to close donor site. Donor site hypersensitivity common.

and bone. However, if the defect is mainly composed of skin, regional flaps can be utilized to good effect without involving distant parts of the body as donor sites. The three main regional flaps used in the reconstruction of the hand are the reversed flow radial forearm flap, the posterior interosseous flap and the dorsal ulnar artery fasciocutaneous flap.

8.6.1 Reversed Flow Radial Forearm Flap (Fig. 8.3)

The distally based radial forearm flap is a workhorse flap for large defects of the hand [31]. The flap relies on retrograde flow in the radial artery which occurs through anastomoses with the ulnar artery at the level of the palmar arch. Depending on which proximal radial artery perforators are included in the flap, it can be raised as fasciocutaneous, adipofascial or osteo-fasciocutaneous flap. It can easily reach the dorsal and palmar aspects of the hand up to the level of the PIP joints and can be designed to contain a strip of brachioradialis or palmaris longus tendons which can be used as part of a single stage tendon reconstruction procedure in complex wounds (Fig. 8.5).

Since the flap requires the sacrifice of the radial artery, it is contraindicated in mutilating hand injuries or limbs with a negative Allen's test where further devascularisation of the hand may have catastrophic consequences. An Allen's test is mandatory before raising this flap and it can be helpful to map out the course of the radial artery pre-operatively using a hand-held Doppler. The vessel runs in the lateral intermuscular septum along a line commencing 1 cm below the midline of the antecubital fossa and continuing in a straight line towards the tubercle of the scaphoid.

A skin paddle of up to 10 × 20 cm can be designed over the volar aspect of the forearm with the radial artery running through the center of the paddle. The skin paddle is easily designed to fill defects with a complex shape and it is also possible to raise multiple skin islands on a single radial

artery – depending on clinical need. Once the design of the skin paddle has been defined, the pivot point of the flap must be selected. This point can lie as far distal as the anatomical snuffbox.

To raise the flap, the arm is abducted, and a tourniquet inflated after exsanguination of the limb. The skin paddle is incised on the radial border and the antebrachial fascia is breached. Traditionally elevation of the flap proceeds subfascially until the lateral intermuscular septum is reached. This is the point at which the cutaneous perforators from the radial artery rise vertically into the overlying skin. The cephalic or basilic veins are often incorporated into the flap as this can be used for venous drainage in cases that develop venous congestion.

The skin paddle may also be raised in a suprafascial plane. The deep fascia surrounding the brachioradialis and flexor carpi radialis tendons are then incised deeply to isolate the perforators arising from the radial artery. The majority of the perforators arising from the radial artery are located in the in the distal or proximal forearm with relatively few in the central or proximal thirds.

When raising the flap, it is important to preserve the paratenon over all the tendons to preserve a graftable wound-bed. A similar dissection is performed from the ulnar side and any deep perforators to adjacent structures (e.g. bone/tendon) can be preserved if a composite flap is desired. If vascularized bone is included in the flap, it is important to harvest this tissue from the volar aspect of the radius, leaving the dorsal and radial cortices intact as this has the smallest impact on the mechanical strength of the bone. Nevertheless, the radius will still be significantly weaker than the contralateral side after harvesting any bone. Therefore, patients should avoid any significant physical stress on the bone for at least 6 weeks post-operatively, with some surgeons performing routine prophylactic plating to minimise the risk of a fracture.

The radial artery is now ligated proximally and mobilised along its deep border. Dissection commences at the elbow

and progresses distally, taking care to preserve a cuff of adipofascial tissue containing the venae comitans and taking care not to injure any branches of the superficial branch of the radial nerve. At all times, care must be taken to ensure that the skin paddle is not pulled off from the intermuscular septum as this predisposes to iatrogenic injury. Once the artery is freed up to the pivot point, the tourniquet can be released, and the flap should be observed for 15 minutes. If venous congestion develops, then any superficial veins harvested with the flap can be anastomosed to a recipient site vein, thereby “turbocharging” the flap. A skin graft (full-thickness preferred) will be needed to resurface the donor site if the skin paddle harvested is wider than 5–6 cm. We recommend quilting the graft to the donor site to improve graft take.

Post-operatively, the hand is splinted with the wrist slightly flexed and the extremity is elevated in a sling. Anticoagulation is not routinely used unless there is evidence of a hypercoagulable state which can occur secondary to massive crush injury or systemic disease. The main disadvantage of this flap are:

1. The unfavorable donor site which is cosmetically poor and can result in loss of wrist mobility and strength secondary to adhesions of underlying tendons and cutaneous nerve entrapment. Patient disability can be minimised by harvesting the flap from the non-dominant hand (if used as a free tissue transfer) and by ensuring that they have access to specialized hand physiotherapy in the post-operative period.
2. Sacrifice of the radial artery.
3. The flap is generally insensate unless a deliberate attempt is made to include branches of the superficial radial nerve in the skin paddle and to perform a neurorrhaphy to sensory nerves at the recipient site.

8.6.2 Posterior Interosseous Artery Flap

The fasciocutaneous posterior interosseous island flap was first described by 1985 by Zancolli and Angrigiani [32]. The flap is based on septocutaneous perforators originating from the posterior interosseous artery. It relies on a retrograde supply which comes from the anterior interosseous artery via an anastomotic vessel which pierces the interosseous membrane, 2 cm proximal to the ulnar styloid. It is useful in reconstruction of defects overlying the dorsum of the wrist and hand as well as the first web space and proximal thumb. The main advantage of the flap is that it does not sacrifice a major vessel of the upper extremity and therefore be harvested without the same concerns about devascularisation of the hand. However, the deep surface of the flap allows for good tendon glide and, when raised as a composite flap containing tendon strips from the extensor carpi ulnaris, it can be used to manage complex, extensor tendon defects.

The skin paddle is designed along a line drawn from the lateral epicondyle of the humerus to the styloid process of the ulna. The pivot point of the flap is marked, 2–3 cm from the styloid process. A hand-held Doppler should be used to identify the perforators running along the axis of the flap and a longitudinally oriented elliptical skin paddle (measuring up to 8 × 15 cm) is then drawn, incorporating as many of these perforators as possible. To minimise the risk of venous congestion, both the length of the flap pedicle as well as the angle of flap rotation should be kept to a minimum. This is a difficult flap to raise safely. Dissection of the flap is delicate and should only be performed by experienced surgeons. Moreover, the majority of the perforators are located distally with only a few in either the middle or proximal thirds of the forearm. The vascular anatomy can also be variable (see below). Therefore, surgeons are advised to only incise one side of the skin paddle to check for the presence of an adequate perforator before committing the patient to a flap that may ultimately fail or develop problems with venous congestion.

To raise the flap, the arm is abducted, and the tourniquet inflated without exsanguination to facilitate identification of the pedicle. The skin paddle is incised along its ulnar border down to the muscle layer. A subfascial dissection is performed until the previously marked perforators can be found within the intramuscular septum which runs between the extensor digiti minimi and extensor carpi ulnaris muscle. Next, a radial incision is made extending through the muscular fascia and a similar dissection is performed to reach the intermuscular septum from the other side. The septum is then carefully freed from the underlying periosteum from distal to proximal, gradually raising the pedicle until the vessel can be traced up to its origin at the ulnar artery. It is at this point that the pedicle is most commonly injured. Identifying the arterial anastomosis with the anterior interosseous artery (distally) *before* ligating the posterior interosseous artery proximally is imperative as up to 5% of the population lack this connection. Once the proximal vessels are clamped, the flap can be lifted free and transposed distally to the recipient site. The tourniquet is then released to confirm flap viability and the donor site defect is either closed directly or resurfaced with a split thickness skin graft if the wound is wider than 4–5 cm.

There are many disadvantages to this flap, including:

1. Variable vascular anatomy and paucity of proximal perforators to perfuse the skin paddle.
2. Poor venous outflow due to the small caliber of the venae comitantes accompanying the posterior interosseous artery. As a result, venous congestion is common and hand elevation is mandatory in the post-operative period.
3. The donor site scar is very noticeable, especially if skin grafts are used and scar revisions are often required.
4. In obese patients use of the posterior interosseous artery flap may result in a bulky reconstruction.
5. Motor branches from the posterior interosseous nerve occasionally need to be transected if they interfere with mobilisation of the pedicle resulting in weakening of the extensor compartment muscles.

8.6.3 *Dorsal Ulnar Fasciocutaneous Flap (the "Becker" flap)*

In 1988, Becker and Gilbert described a fasciocutaneous flap based on the ascending branch of the dorsal ulnar artery [33–35]. Shortly after branching off from its parent vessel, the dorsal ulnar artery divides into a retrograde (recurrent) branch which supplies the fasciocutaneous tissues of the distal forearm and an antegrade branch which supplies the dorsum of the hand and wrist. The retrograde branch serves as the vascular supply for the dorsal ulnar fasciocutaneous flap and it is accompanied by two venae comitantes which provide the venous drainage for the flap. The dorsal ulnar branch is one to three millimeters in diameter at its origin and can be traced back to the ulnar artery at a point located two to five centimeters proximal to the pisiform in a line extending to the medial humeral epicondyle. Infrequently, the pedicle arises from the anterior interosseous artery. Its origin marks the pivot point of the flap as well as the proximal margin of the skin paddle. The skin paddle itself can be a maximum of 9 cm in width and 20 cm in length and can be rotated 180° to cover distal defects. Dorsally, the limit of the skin paddle lies along the extensor communis tendon of the fourth finger. The radial limit of the skin paddle lies along the edge of the palmaris longus tendon. The dorsal ulnar fasciocutaneous flap is particularly useful for reconstructing medium-sized soft-tissue defects of the dorsum of the hand as far distally as the first web space as well as the ulnar aspect of the palm. Flap harvest does not sacrifice any major vessel in the hand and allows for prompt rehabilitation and early discharge from hospital.

The procedure is usually performed under brachial plexus block with loupe magnification. The origin of the dorsal ulnar artery is identified using a hand-held Doppler. The tourniquet is inflated without limb exsanguination to aid pedicle dissection. The proximal/dorsal margin of the skin paddle is incised first. Sharp dissection proceeds down to the muscle creating a subfascial plane. Care is taken to preserve

the dorsal cutaneous branch of the ulnar nerve. Elevation of the flap is continued from proximal to distal until the retrograde (recurrent) branch of the dorsal ulnar artery is identified running on the deep surface of the flap. The pedicle is traced down to its origin from the ulnar artery by retracting the flexor carpi ulnaris muscle. The skin is then completely islanded by freeing the tissues along the volar side of the flap. A peninsular flap can also be designed. However, this results in formation of a significant dog-ear at the base of the flap when the tissue is transposed and often requires later revision. When rotating the flap into the recipient site, compression of the pedicle can be kept to a minimum by excising the local subcutaneous tissue and creating a sulcus into which the pedicle can be placed. The tourniquet is now released to confirm satisfactory perfusion of the flap.

In cases with obvious venous congestion intra-operatively, an additional anastomosis with one of the subcutaneous veins contained within the flap can be performed to augment drainage. If the flap is less than 5 cm in width, the donor defect can often be closed primarily, after undermining of the wound margins. For larger skin paddles, the defect must be resurfaced with a skin graft.

The main disadvantages of this flap include:

1. The poor cosmetic appearance of the donor site scarring with possible numbness or discomfort arising with the territory of the dorsal branch of the ulnar nerve.
2. Venous congestion. This is a consequence of the flap design which inevitably results in retrograde venous drainage.
3. Lack of sensation in the skin paddle (Table 8.3).

Key Points

- Soft-tissue defects in the hand must be managed aggressively to minimise the risk of permanent disability of the affected extremity. Reconstruction aims to provide stable and durable soft-tissue cover which permits the free movement of the neighboring joints and mimics the tissues which have been lost, both functionally and aesthetically.

TABLE 8.3 Overview of regional flaps in upper extremity reconstruction

Flap	First described	Design	Vascular supply	Neural supply	Indications	Advantages	Limitations
Reverse radial artery flap	*Stock et al. (1981)* [31]; *Lu KH (1982)* [36]	Doppler examination is performed to mark out the course of the radial artery, which lies along a line commencing 1 centimeter below the midline of the antecubital fossa and terminates at the tubercle of the scaphoid. A skin paddle can then be liberally designed over the course of the vessel. Flaps as large as 10 × 20 cm have been described. Multi-islanded and composite designs are possible depending on clinical situation.	Radial artery – reverse flow from ulnar artery through deep palmar arch.	Usually insensate. The lateral or medial antebrachial nerves can be included in the Flap and coapted to local sensory nerves.	Can provide coverage of large defects of both the dorsum of hand and palm. Workhorse flap for hand reconstruction.	Large variability in flap composition and design. Supplies thin and pliable tissue.	Sacrifice of major artery in upper extremity. Very conspicuous donor site which requires skin grafting if defect wider than 5–6 cm. Impairment of tendon glide at donor site.

Posterior interosseous artery flap	*Zancolli and Angrigiani (1985)* [32]	Elliptical skin paddle measuring up to 8 × 15 cm drawn over a line extending from lateral epicondyle of the humerus to the ulnar styloid. The flap is centered over fasciocutaneous perforators which lie along this line and are identified pre-operatively by Doppler examination. Pivot point is located 2–3 cm proximal to the ulnar styloid.	Septocutaneous perforators coming off the posterior interosseous artery. Retrograde supply via communicating vessels from the anterior interosseous artery which pierce the interosseous membrane 2–3 cm proximal to ulnar styloid.	Usually insensate. Ulnar cutaneous antebrachial branch can be incorporated but this is rarely performed.	Defects of the dorsum of the hand and wrist. Can also be used in first webspace and proximal thumb reconstruction.	Does not sacrifice a major artery of the upper extremity. Less disruption of the lymphatic drainage of the hand when compared with volar based flaps.	Dissection difficult and should only be performed by experienced surgeons. Venous congestion is common. Motor nerve branches may need to be divided if cross over the pedicle. Donor site needs skin grafting if flap wider than 4–5 cm.

(continued)

TABLE 8.3 (continued)

Flap	First described	Design	Vascular supply	Neural supply	Indications	Advantages	Limitations
Reverse ulnar artery perforator flap (Becker)	*Becker and Gilbert (1988)* [33–35]	Elliptical fasciocutaneous flap designed on ulnar border of the distal forearm. Raised as a peninsular or island flap. The pedicle Emerges 2–5 cm proximal to the pisiform and serves as the pivot point of the flap and its proximal margin. Although usually used for smaller defects, the flap can be designed to a maximum of 20 cm in length and 9 cm in width.	Ascending branch of the dorsal ulnar artery.	Dorsal branch of ulnar nerve.	Ulnar border of hand and hypothenar eminence. Defects of the volar wrist and hand dorsum as far as the first webspace.	Does not sacrifice a major artery of the upper extremity. Reliable anatomy and relatively straightforward dissection.	Not suitable for coverage of defects on the radial side of the palm. Venous congestion common due to retrograde venous drainage. Risk of iatrogenic injury to ulnar artery and nerve.

Judicious selection of cases allows most small wounds to be managed with dressings. For the remainder, local flaps can be used to manage small to moderate sized wounds, introducing sensate tissue into the defects and avoiding the need for a more complex reconstruction. Larger defects can be readily resurfaced with regional flaps originating in the forearm with only a small minority needing free-tissue transfer.

- Detailed descriptions of the flaps included in this article are easily obtained from the literature. However, continuing advances in our understanding of the vascular anatomy of the upper extremity will allow new modifications to be introduced in the future with the aim of reducing the donor site morbidity and to improve the functional and aesthetic outcomes.
- Hand surgeons must possess a detailed knowledge of all the reconstructive options in the upper extremity to ensure that they can select the best operative solution for a particular individual. Furthermore, the limitations of individual flaps must be understood so that changes in the preliminary treatment plan can be instituted depending on the clinical need.

References

1. Neumeister MW, Brown RE. Mutilating hand injuries: principles and management. Hand Clin. 2003;19:1–15.
2. McGregor IA. Flap reconstruction in hand surgery: the evolution of presently used methods. J Hand Surg. 1979;4:1–10.
3. Rehim SA, Chung KC. Local flaps of the hand. Hand Clin. 2014;30:137–51.
4. Yannascoli SM, Thibaudeau S, Levin LS. Management of soft tissue defects of the hand. J Hand Surg. 2015;40:1237–44.
5. Kenney RJ, Hammert WC. Physical examination of the hand. J Hand Surg. 2014;39:2324–34; quiz 34.
6. Quaba AA, Davison PM. The distally-based dorsal hand flap. Br J Plast Surg. 1990;43:28–39.

7. Tranquilli-Leali E. Ricostruzione dell' apice delle falangi ungueali mediante autoplastica volare peduncolata per scorrimento. Infort Trauma Lavoro. 1935;1:186–93.
8. Atasoy E, Ioakimidis E, Kasdan ML, Kutz JE, Kleinert HE. Reconstruction of the amputated finger tip with a triangular volar flap. A new surgical procedure. J Bone Joint Surg Am. 1970;52:921–6.
9. Elliot D, Moiemen NS, Jigjinni VS. The neurovascular Tranquilli-Leali flap. J Hand Surg (Edinburgh, Scotland). 1995;20:815–23.
10. Geissendörfer H. Beitrag zur Fingerkuppenplastik; 1943.
11. Kutler W. A new method for finger tip amputation. J Am Med Assoc. 1947;133:29.
12. Segmuller G. Modification of the Kutler flap: neurovascular pedicle. Handchirurgie. 1976;8:75–6.
13. Lanzetta M, St-Laurent JY. Pulp neurovascular island flap for finger amputation. J Hand Surg. 1996;21:918–21.
14. Venkataswami R, Subramanian N. Oblique triangular flap: a new method of repair for oblique amputations of the fingertip and thumb. Plast Reconstr Surg. 1980;66:296–300.
15. Evans DM, Martin DL. Step-advancement island flap for fingertip reconstruction. Br J Plast Surg. 1988;41:105–11.
16. Lai CS, Lin SD, Yang CC. The reverse digital artery flap for fingertip reconstruction. Ann Plast Surg. 1989;22:495–500.
17. Brunelli F, Vigasio A, Valenti P, Brunelli GR. Arterial anatomy and clinical application of the dorsoulnar flap of the thumb. J Hand Surg. 1999;24:803–11.
18. Brunelli F. Dorso-ulnar thumb flap. Annales de Chirurgie de la Main et du Membre Superieur : Organe Officiel des Societes de Chirurgie de la Main = Ann Hand Upper Limb Surg. 1993;12:105–14.
19. Cronin TD. The cross finger flap: a new method of repair. Am Surg. 1951;17:419–25.
20. Gudin M, Pangman WJ. The repair of surface defects of fingers by trans-digital flaps. Plast Reconstr Surg. 1950;5:368.
21. Atasoy E. Reversed cross-finger subcutaneous flap. J Hand Surg. 1982;7:481–3.
22. Gatewood. A plastic repair of finger defects without hospitalization. J Am Med Assoc. 1926;87:1479.
23. Iselin F. The flag flap. Plast Reconstr Surg. 1973;52:374–7.
24. Vilain R, Dupuis JF. Use of the flag flap for coverage of a small area on a finger or the palm. 20 years experience. Plast Reconstr Surg. 1973;51:397–401.

25. Moberg E. Aspects of sensation in reconstructive surgery of the upper extremity. J Bone Joint Surg Am Vol. 1964;46:817–25.
26. O'Brien B. Neurovascular island pedicle flaps for terminal amputations and digital scars. Br J Plast Surg. 1968;21:258–61.
27. Foucher G, Smith D, Pempinello C, Braun FM, Citron N. Homodigital neurovascular island flaps for digital pulp loss. J Hand Surg (Edinburgh, Scotland). 1989;14:204–8.
28. Elliot D, Wilson Y. V-Y advancement of the entire volasoft tissue of the thumb in distal reconstruction. J Hand Surg: Br Eur Vol. 1993;18:399–402.
29. Holevich J, Paneva-Holevich E. Bipedicled island flap. Acta Chir Plast. 1971;13:106–16.
30. Foucher G, Braun JB. A new island flap transfer from the dorsum of the index to the thumb. Plast Reconstr Surg. 1979;63:344–9.
31. Stock W, Muhlhauer W, Biemer E. The neurovascular forearm island flap. Zeitschrift fur plastische Chirurgie. 1981;5:158–65.
32. Zancolli EA, Angrigiani C. Posterior interosseous island forearm flap: vascular anatomy. Umea: European Hand Surgery Course; 1985.
33. Becker C, Gilbert A. The ulnar flap — description and applications. Eur J Plast Surg. 1988;11:79–82.
34. Becker C, Gilbert A. The ulnar flap. Handchirurgie, Mikrochirur gie, plastische Chirurgie: Organ der Deutschsprachigen Arbeitsgemeinschaft fur Handchirurgie: Organ der Deutschsprachigen Arbeitsgemeinschaft fur Mikrochirurgie der Peripheren Nerven und Gefasse. 1988;20:180–3.
35. Becker C, Gilbert A. The cubital flap. Annales de Chirurgie de la Main: Organe Officiel des Societes de Chirurgie de la Main. 1988;7:136–42.
36. Lu KH. The forearm radial arterial turnover flap and its clinical applications. Zhonghua wai ke za zhi [Chin J Surg]. 1982;20:695–7.. 704.

Chapter 9
Hand Fractures

Roshan Vijayan

Managing a patient referred with a fracture of the hand can be daunting for the inexperienced. This is not least because there is very little teaching or exposure to the subject during medical school or posts in other specialties, and the management of hand fractures varies widely amongst hand surgeons. It can therefore appear a confusing area.

In general most plastic surgeons deal with hand fractures distal to the carpal bones. Carpal and wrist fractures usually are the remit of orthopaedics, but check your department's policy.

Decision making in hand fractures is mostly pattern recognition. Experienced clinicians have seen many fractures and recall the management of recurrent common fractures. Until you have gained this experience, it is a good idea to ask for advice once you have seen and assessed the patient.

The key as always, is to remember basic principles; a thorough history and examination, rather than viewing the radiographs in isolation.

R. Vijayan (✉)
Department of Plastic Surgery, Royal Free Hospital, London, UK

P. Singh (ed.), *Hand Trauma in Clinical Practice*, In Clinical Practice, https://doi.org/10.1007/978-3-030-10844-1_9

9.1 Assessment

9.1.1 History

A thorough history as always is important. It is particularly essential to ascertain:

Patient-specific factors:

- Age, hand dominance, occupation, comorbidities.

Injury-specific factors:

- Date and mechanism, open or closed fracture.

9.1.2 Examination

Look for deformity, swelling and mal rotation (when the digit has 'swivelled' on its long axis).

"Please point with one finger to where is most painful" is a useful statement.

Confirm the absence of neurovascular deficit. The fingertip should be pink with a normal capillary refill time, and sensate. Some subjective paraethesiae may be secondary to swelling.

Rotation is best assessed in two ways.

1. Ask the patient to spread their fingers and hold them extended. Then look at the fingertips of both hands end on. A rotated digit will have a rotated nailplate.
2. Ask the patient to put both hands on the table, palms up. Now ask them to curl all the fingers into a closed fist. A rotated digit will appear to 'scissor' i.e. cross the adjacent digit. In a normal flexion cascade, all fingers should point towards the scaphoid tubercle. Patients will often be reluctant to move a fractured hand. Reassure them that they won't cause any harm with this manoeuvre, and encourage them to open and close the hand repeatedly, to overcome their initial reluctance and stiffness.

9.2 Radiographs

Radiographs should always be AP, oblique and lateral. Ideally the less dressings or splints in place the better, to obtain a clear view.

If you identify a fracture, look carefully to exclude another one elsewhere in the hand.

Hand fractures make more sense when considering the surrounding soft tissues. Consider where the tendons and ligaments insert, and this will often explain why a particular deformity results. A common concept, though often poorly understood, is of fracture *stability*. Stable fractures, are those that tend not to displace when the hand is judiciously mobilised. Unstable fractures by contrast are at high risk of 'slipping'. Assessment of stability requires an appreciation of the fracture configuration, the pull of soft tissue attachments (ligaments and tendons), and the presence or absence of stabilising callus.

Remember that significant fractures of the metacarpals and phalanges, i.e. those requiring operative fixation, will be displaced. Undisplaced fractures can usually be splinted and followed up by a hand therapist to ensure the patient mobilises.

However, this is not to say that small fractures are insignificant. A small fragment may represent an avulsion fracture from the pull of a tendon or ligament.

9.3 MUA

MUA is manipulation under anaesthesia. Manipulating a displaced fracture is usually a safe and helpful manoeuvre to attempt. In a very displaced fracture, it may improve perfusion of the digit and reduce pain, and may even obviate the need for operative fixation if an acceptable reduction can be achieved.

The aim of MUA is to restore a more anatomical position. In most cases a local anaesthetic block can be used:

- Digital nerve block for middle phalangeal fractures
- Metacarpal block for proximal phalangeal fractures
- Haematoma block or wrist block for metacarpal fractures

A mixture of 1% lignocaine and 0.25% or 0.5% bupivacaine is a good choice as it combines the benefits of a quick onset, short acting anaesthetic with a slower onset, longer acting agent.

Correlate the radiograph with the patient's hand and consider what manoeuvre will improve the bone alignment. Usually, starting with traction by pulling the digit, is a useful manoeuvre as it disimpacts the fracture site. Apply a prolonged firm pull to the finger for a minute or longer, then correct any obvious rotation or angulation.

Send the patient for a post-reduction check radiograph. It is often safe to do this without a splint to get a good view, but if the fracture feels unstable, then you may need to apply a splint before the radiograph.

Before and after any MUA be careful to assess the perfusion of the digits and document this.

9.4 Splinting

The idea of splinting is to immobilise the fractured bone and or adjacent joints, to minimise movement of the fracture while stabilising callus is forming. A further benefit is to reduce pain and keep the patient comfortable. In adults, immobilisation of small joints beyond 3 weeks can lead to significant stiffness that may never be fully overcome with rehabilitation.

For this reason, avoid splinting uninvolved digits and joints unnecessarily, and aim for early protected mobilisation.

For most metacarpal and proximal phalanx fractures, a simple resting splint can be applied made from plaster of Paris (POP). This maintains the POSI (position of safe immobilisation), with the wrist extended (30°), MCPJs flexed (70–90°) and IPJs fully extended. This position minimises joint stiffness secondary to tightening of the collateral ligaments by splinting these ligaments at full stretch.

For middle and distal phalangeal fractures a Zimmer splint can usually be applied to immobilise just the involved digit. Neighbour/buddy strapping to an adjacent digit can also be useful.

Avoid circumferential casts made of POP or fibreglass in the acute setting, as these are difficult to subsequently remove, and will not accommodate any early swelling.

9.5 General Counselling

Tell the patient with a fractured hand to keep the hand elevated, above heart level as much as possible. Advice varies, but usually at least 48 hours is useful. If a sling is provided, tell the patient to exercise their uninvolved joints (shoulder, elbow and wrist) regularly to prevent stiffness. Keep the splint clean and dry.

Ensure that you have a clear follow up plan arranged. Either they will be contacted by a hand therapist, or will return for surgery, or will be reviewed in the outpatient clinic. This should be documented.

9.6 To Fix or Not?

Whether to fix a particular fracture and the manner of doing so is often a subject of great contention between hand surgeons. There are some basic principles:

- *Unstable* fractures are much more likely to require fixation than *stable* fractures
- Fixing a fracture should facilitate early active movement, to avoid stiffness and maintain function. This is particularly true of ORIF, where the additional inflammation, oedema and scarring will otherwise lead to significant stiffness and tendon adhesions. There is little point in opening and fixing a fracture, and then leaving it immobilised for several weeks. Early mobilisation occurs within a few days post-operative, or even immediately! In the case of K-wires, the aim is to reduce and stabilise a very displaced fracture for just long enough for stabilising callus to form. This will often not be visible on the radiograph, but will provide sufficient early 'stickiness' to prevent the fracture from displacing, once the wire is removed and early protected mobilisation commenced.

- Young children often do not require more than an MUA.
- Treat the patient not the radiograph. Normal function is unlikely to be improved by an operation.
- Aim to fix fractures within a week. After this it can be difficult to reduce a closed fracture without opening it.

9.7 Open Fractures

Any hand fracture with an overlying wound should be managed as a special case.

In general, these should have as thorough a washout as is possible in the early setting. In A&E, this usually means a local anaesthetic block and irrigation with saline. Then dress and splint the hand.

Admit the patient, elevate the hand in a Bradford sling, and prescribe IV antibiotics, (check Trust guidelines, usually co-amoxiclav if the patient is not penicillin allergic).

Open fractures should usually be washed out definitively and fixed if required in the operating theatre the next day or sooner. There may be associated soft tissue repairs required also (e.g. nerve, tendon).

An exception to this is tuft fractures of the distal phalanx. These are usually associated with a nailbed injury, and although technically open fractures, can be safely managed as an outpatient, covered with oral antibiotics.

9.8 Consent

It is usually sensible to advise most patients requiring hand fracture fixation that either general or regional anaesthesia will be required. This is usually because an arm tourniquet is employed, which is otherwise intolerable for more than 10 minutes. The patient should fast for 6 hours before the proposed surgery and stop clear fluids 2 hours prior.

Always mention the possibility of ORIF even when only percutaneous pinning (K-wires) is likely to suffice. When writing the consent form, avoid abbreviations (ORIF, and 'L', 'R').

K-wires are usually removed in the outpatient clinic between 3 and 4 weeks after surgery, depending on the fracture configuration.

Mention in particular the risk of:

- Stiffness
- Infection
- Neurovascular damage
- Mal/delayed/non- union
- Chronic regional pain syndrome (CRPS).
- Immobilisation in a splint, and hand therapy-supervised rehabilitation (not a risk, but still worth documenting on the consent form)

It is best to be speak in general terms to the patient and in more specific terms to the surgeon. In an open fracture where there is the possibility of other soft tissue repairs it is useful to include the clause "+/− repair of any other damaged structure e.g. tendon/ligament/nerve/vessel". However, when communicating with the surgeon e.g. in your documentation and on the theatre booking form, try to specify what soft tissue damage is likely from your examination findings.

9.9 Common Fractures

9.9.1 Distal Phalanx Tuft Fractures (Fig. 1.2)

These are commonly associated with nailbed injuries. They rarely require any specific management other than repair of the associated nailbed wound and washout. There is no harm in immediate mobilisation. A more proximal transverse or oblique fracture (Fig. 9.1) through the waist of the distal phalanx is sometimes managed with an axial K-wire, although many would still manage this non-operatively in a splint.

9.9.2 Fifth Metacarpal Neck Fractures (Fig. 9.2)

Also known as a boxers' fracture. Criteria for conservative vs surgical management varies widely, but a sensible approach is to ask yourself:

FIGURE 9.1 Oblique fracture of distal phalanx

FIGURE 9.2 Fifth metacarpal neck fracture

- Is the finger mal rotated?
- Is there a significant extensor lag, because of shortening?
- Is there a sharp prominent dorsal spike that could cause an attrition rupture of the overlying extensor tendon?
- Is the head so angulated that it can be felt in the palm? (if so it is likely that there will be a significant extensor lag also)

If the answer is no to these, then conservative management is reasonable. This approach may be more pragmatic than using an arbitrary degree of measured angulation as the threshold for surgery.

Angulation of a fifth metacarpal neck fracture can usually be improved with an MUA under LA. In addition to axial traction, consider the Jahss manoeuvre (flex the MCPJ fully, then apply upward pressure on the proximal phalanx to use it as a piston to push the metacarpal head up).

9.9.3 Bony Mallet Fractures (Fig. 9.3)

Ask yourself:

FIGURE 9.3 Bony mallet injury

- Is there joint subluxation of the DIPJ?
- Is the articular fragment significantly displaced after an MUA/fully extending the DIPJ passively and holding it with a splint)?

If the answer is no, then conservative management in a splint is usually best. The splint must be maintained for 6 weeks, with hand therapy supervision.

9.9.4 PIPJ Pilon Fractures

Usually an axially loading force to the fingertip. The result is an intra-articular comminuted displaced fracture of the P2 base. These are challenging to manage, but a common approach is to apply a dynamic external fixation frame such as a Suzuki or Giddins frame. The idea is to apply 'ligamento-taxis'; traction to the ligaments attached to the fragments, thereby gradually reversing the original axial force that caused the deformity.

9.9.5 Bennett's Fracture

This is an intra-articular fracture of the thumb base. Operative fixation with K- wires is commonly employed, due to the distracting forces on the fracture (the volar oblique ligament stabilising the small fragment, while the APL tendon pulls and distracts the metacarpal).

Chapter 10
Anaesthesia for Upper Limb Surgery

Raj Shah

Anaesthesia is required for surgical procedures to be performed. A thorough knowledge of the principles of anaesthesia, and when each type of anaesthesia is appropriate to use is important.

10.1 Principles of Anaesthesia

Upper limb surgery can be performed using general or regional anaesthesia. Both forms of anaesthesia require a thorough pre-operative assessment. During this visit the anaesthetist will conduct a comprehensive review of the patient's health and history of previous anaesthetic experience. The anaesthetist will enquire about any comorbidites, exercise tolerance, regular medications and doses, and drug allergies, as well as any history of gastric reflux, smoking and alcohol use. This is then followed by a general examination of the patient's cardiovascular and respiratory system, and a thorough airway assessment for range of cervical neck movement, dentition state and mouth opening.

R. Shah (✉)
Department of Regional Anaesthesia, Royal Free Hospital, London, UK
e-mail: Raj.shah@doctors.org.uk

P. Singh (ed.), *Hand Trauma in Clinical Practice*, In Clinical Practice, https://doi.org/10.1007/978-3-030-10844-1_10

For any case listed for surgery, it is paramount that patients are starved to reduce the gastric volume and risk of aspiration under anaesthesia. Fasting guidelines are available within each anaesthetic department, which require patients to be starved for up to 6 hours for food and milky drinks. Small volumes of clear fluid and water can be consumed up to 2 hours prior to surgery.

Following the pre-operative assessment, the anaesthetist will discuss anaesthetic options for upper limb surgery with the patient.

10.2 General Anaesthesia

General anaesthesia is a state of controlled unconsciousness. General anaesthesia involves preparation of drugs and equipment, and the presence of an anaesthetist and trained assistant. Induction of general anaesthesia commonly involves insertion of a peripherally-sited venous cannula (22 or 20G), and attachment of monitoring to record the patient's vital organ parameters (oxygen saturation, ECG, non-invasive blood pressure). Patients are pre-oxygenated with 100% oxygen for a period of 3–5 minutes prior to induction of anaesthesia via a tight-fitting mask, and titrated amounts of drugs that induce a loss of consciousness in one arm-brain circulation time are administered. Commonly used intravenous drugs include intravenous fentanyl and propofol. Airway patency with either a face mask, supraglottic airway devices e.g. laryngeal mask, or tracheal intubation is essential as general anaesthesia results is loss of pharyngeal tone and airway occlusion by the tongue.

Anaesthesia during surgery is commonly maintained with volatile agents delivered into the patient's breathing system using an anaesthetic machine, which provides amnesia, analgesia and muscle relaxation. However, additional drugs may need to be administered to completely ameliorate the stress response to surgical stimulation. As a result, intravenous analgesia such as paracetamol and a mixture or short and/or

longer acting opioids e.g. fentanyl or morphine may be required.

An explanation of the risks and potential complications of general anaesthesia must be provided to patients at the initial pre-operative assessment. These discussions commonly address side effects such as post-operative nausea and vomiting (PONV), and risks such as damage to teeth, oral mucosa and sore throat following insertion of equipment to maintain airway patency, and damage to skin, nerve or muscle during inappropriate positioning for surgery.

10.3 Regional Anaesthesia

Regional anaesthesia involves the injection of local anaesthetic near peripheral nerves to provide anaesthesia and analgesia for patients undergoing surgery. It provides an alternative way to perform surgery without a general anaesthetic. The contraindications to regional anaesthesia include patient refusal despite complete explanation, an uncooperative patient, localised sepsis, anticoagulation or coagulopathy, trauma or burns over injection site, or altered anatomy.

Patient information leaflets are available which provide an in-depth explanation of the insertion, sensation, and duration of the nerve block as well as benefits, risks and complications.

The intended benefits of regional anaesthesia include the avoidance of general anaesthesia and its associated risks and complications, earlier mobilisation and analgesia. Regional anaesthesia carries certain risks and complication. These include bleeding and infection around the injection site, inadvertent vascular injection, incomplete anaesthesia, and temporary and/or permanent nerve damage.

As with all forms of anaesthesia, full monitoring is attached to the patient, intravenous access is placed in the contralateral hand, strict aseptic conditions are applied, and a trained assistant present throughout the procedure.

10.3.1 Ultrasonography

Ultrasound-guided regional anaesthesia (UGRA) is now the preferred method for performing nerve blocks, and has dramatically improved the localisation of nerves and surrounding structures. Ultrasound provides detailed illustration of anatomy for nerve blocks in real-time, improves accuracy of needle placement which can reduce the risks of complications such as intravascular or intraneural injection, and may reduce the total volume of local anaesthesia required for successful blocks. Commonly, a linear array transducer (6–18 MHz, 25 mm) is used and provides excellent resolution and image quality. It must be noted that sonographic artefacts may affect the quality of the image.

10.3.2 Anatomy

The anaesthetists knowledge about the sensory and motor nerve supply is paramount, to ensure the correct block is performed for surgery on the upper limb.

Depending upon the location of injury, proposed surgery and use of tourniquet, regional techniques can be divided into brachial plexus or peripheral forearm nerve block.

10.3.3 Brachial Plexus Block

The majority of the upper limb has its nerve supplied by the ipsilateral brachial plexus, and its superficial location allows easy location with ultrasound. There are various approaches to perform this block, but we shall focus specifically on the axillary and supraclavicular technique. For a more comprehensive description on all brachial plexus blocks, we encourage the reader to refer to specialised texts.

Axillary Approach

This block is routinely performed for surgery on the hand, forearm and elbow. Patients are positioned in the supine posi-

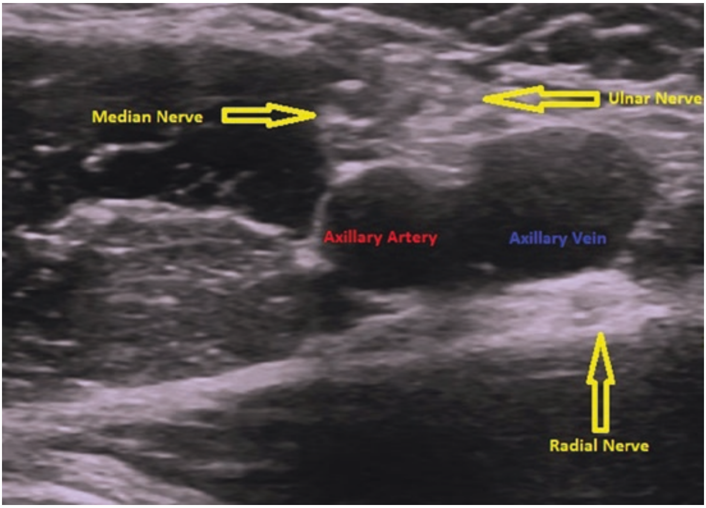

FIGURE 10.1 Ultrasound image of Axillary brachial plexus block

tion with the arm placed out. An ultrasound probe placed in the axilla will identify the axillary brachial plexus nerves as hyperechoic structures surrounding the axillary artery (Fig. 10.1). Conventionally a 100 mm 22G insulated needle is used to equally distribute a calculated volume, based upon the weight of the patient, using an in-plane technique around each of the nerves. Limitations to this approach may include difficulties in identifying the radial nerve, so additional local anaesthesia may be required through surgical infiltration.

Supraclavicular Approach

This block provides the best coverage of sensory blockade, but its proximity to the apex of the lung and therefore risk of potential iatrogenic pneumothorax has decreased its use amongst anaesthetists. Use of ultrasound and identification of the pleura prior to injection has significantly improved its safety. Patients are positioned supine with the head turned slightly away from the side being blocked. An ultrasound probe placed above the clavicle will identify the subclavian artery, the first rib and pleura, and the trunks and divisions of

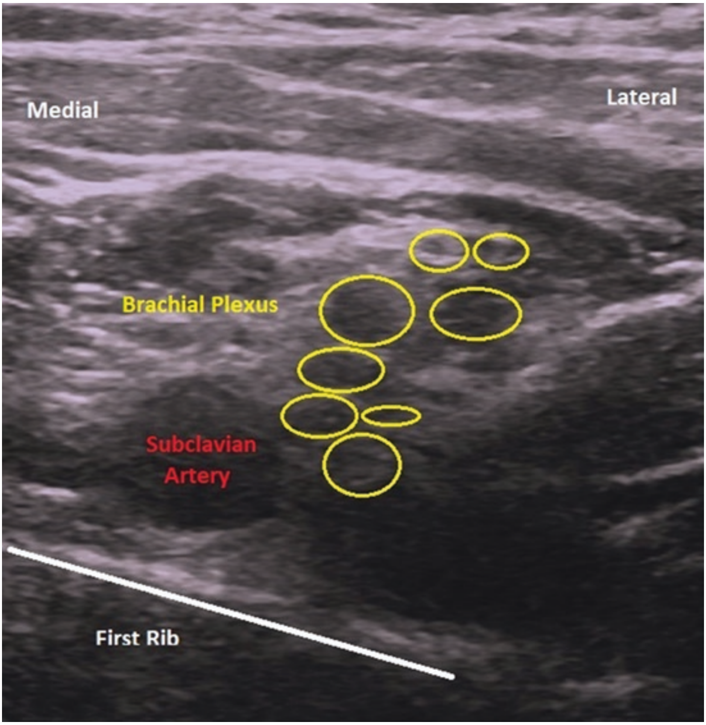

FIGURE 10.2 Ultrasound image of Supraclavicular brachial plexus block

the brachial plexus nerves (Fig. 10.2). Conventionally a 50 or 100 mm 22G insulated needle is used to equally distribute a calculated volume, based upon the weight of the patient, using an in-plane technique around each of the nerves. Specific complications that may occur with this approach include iatrogenic pneumothorax, phrenic nerve palsy and Horner's syndrome.

10.4 Peripheral Forearm Blocks

Peripheral forearm blocks involve injecting local anaesthetic around the median, ulnar and radial nerves. These can be used as pure regional anaesthesia or as analgesia in conjunc-

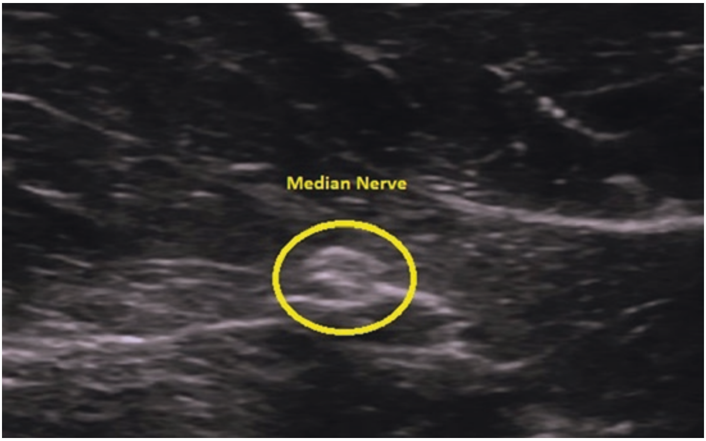

FIGURE 10.3 Ultrasound image of median nerve at the forearm

tion with general anaesthesia. Patients are positioned supine with their arm placed out. An ultrasound probe placed at the mid-forearm can easily identify the median nerve, with the ulnar nerve closely related to the ulnar artery, and radial nerve best visualised above the later aspect of the elbow in the spiral groove of the humerus (Figs. 10.3 and 10.4). Conventionally a 50 mm 22 or 25G insulated needle is used to equally distribute 5 ml of local anaesthetic around each nerve.

10.5 Drugs for Regional Anaesthesia and Local Anaesthetic Toxicity

Local anaesthetic agents are drugs used to provide regional anaesthesia and nerve blocks. They are chemically divided into either esters or amides and act by blocking the fast sodium channel in neuronal membranes. Commonly used drugs in practice include Bupivacaine, Lignocaine, Prilocaine and Ropivacaine. Knowledge with regards to their safety doses, speed of onset and duration of action is paramount.

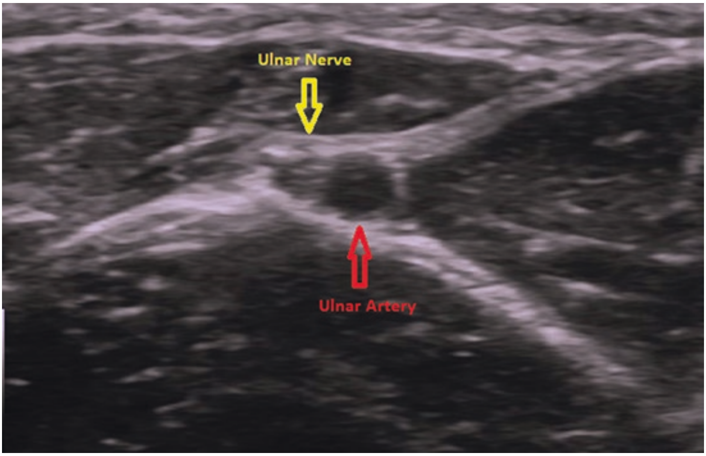

FIGURE 10.4 Ultrasound image of ulnar nerve at the forearm

Local anaesthetic toxicity has an incidence of 7.5 per 10,000 cases, and the proposed mechanism for its development is thought to be related to the accumulation of harmful plasma levels of local anaesthetic as opposed to direct vascular injection. Diagnosis may be challenging, and anaesthetists must be vigilant for any clinical symptoms evolving which may affect the cardiovascular or central nervous systems, which depends upon the dose absorbed. The Association of Anaesthetists of Great Britain & Ireland (AAGBI) have published guidelines for the management of local anaesthetic toxicity, which includes stopping any local anaesthetic infiltration, calling for help, providing airway and cardiovascular support, and administering intravenous lipid emulsion as per the AAGBI documented regimen.

Chapter 11
Consent

Amitabh Thacoor

The surgeon discussing treatment with the patient should be suitably trained and qualified to provide the treatment in question and have sufficient knowledge of the associated risks and complications, as well as any alternative treatments available for the patient's condition.

Royal College of Surgeons of England – Consent: Supported Decision Making (2016) [1]

Informed consent is required before surgical procedures can be carried out. The patient must be informed of the potential benefits of the procedure as well as the complications and potential risks. The likelihood of particular risks occurring should also be explained with tailoring to individual patients. For example, infection risk will be higher in smokers, immunocompromised patients and those with diabetes; bleeding will be more likely if the patient has a coagulopathy. All alternative treatment modalities should also be discussed, and all the patient's questions answered so any consent then given is

A. Thacoor, MBChB, MRCS (✉)
Department of Plastic Surgery, Royal Free Hospital, London, UK
e-mail: Amitabh.thacoor@doctors.org.uk

P. Singh (ed.), *Hand Trauma in Clinical Practice*, In Clinical Practice, https://doi.org/10.1007/978-3-030-10844-1_11

fully informed. In this chapter we will highlight the risks and complications that must be discussed and documented on the consent form.

11.1 General Consent Complications

- **Pain –** Patients will almost always experience discomfort and pain post-operatively, and this can contribute to reduced mobility and recovery. This can usually be alleviated with oral analgesia or long acting local anaesthetic blocks.
- **Swelling –** Hand surgery will inevitably result in post-operative oedema. This can be alleviated with hand elevation and early mobilisation. Patients should be counselled on the importance of hand elevation post-operatively to reduce pain and swelling and consequently, reduce analgesic requirements. Furthermore, it is vital to promptly remove any rings from the patient's fingers, which may later constrict the digits and cause vascular compromise.
- **Bleeding –** The amount of blood loss can be reduced through the use of a tourniquet and meticulous haemostasis intra-operatively. However, there is always a small amount of bleeding, and one must be prepared for the potential for more significant blood loss. A note should be made of the patient's views on blood transfusion, particularly when consenting for more extensive operations, as this may determine subsequent management.
- **Infection** – Surgical site infections requiring antibiotics and regular dressing changes are common but steps can be taken to minimise this risk. The risk of infection is intricately liked to both patient factors (such as smoking, diabetes, immunocompromised state) as well as injury factors (such as mechanism, contamination and duration of injury). Patients should be appropriately counselled on smoking cessation and clinical signs of infection to be aware of (such as worsening erythema, tenderness or pus).

Infection may be confined to the skin only or deeper tissues, including bone- which may necessitate long-term antibiotics, further debridement and removal of any metalwork if present.

- **Scarring –** It is important to inform the patient of the expected location of the surgical scar and the potential need for extending incisions beyond the original injury. This is particularly important in penetrating injuries, or those involving cut flexor tendons which may need to be chased in to the hand and rarely, in to the forearm. Patients should also be informed of the scar maturation process and the potential for keloid or hypertrophic scarring.
- **Stiffness –** This is often the result of immobilising the hand or upper limb in a POP or thermoplastic splint, but can also be related to the injury, damage to tendons, ligaments or muscle, and infection. Digital immobilisation should be restricted only to the affected joints where possible and hand immobilisation in the Edinburgh position with prompt referral to a hand therapist will minimise the risk of stiffness. The resting position ensures that the collateral ligaments at the MCPJ and the IPJ are immobilised at their maximal length to prevent contractures. Patients with tendon or bony injuries must be informed of the often arduous and lengthy hand therapy commitment they will have to make to regain maximum function.
- **Requirement for further surgery –** This is most commonly required in cases of severe infections and high-pressure injuries where primary closure is contraindicated and which may require a return to theatre for a ‘second-look’ or further washout or repair of structures. For elective procedures or fracture fixations, the potential need to remove metalwork or to perform tenolysis at a later stage validates mentioning this risk on the consent form.
- **Damage to adjacent structures –** Inadvertent iatrogenic injury can occur to surrounding structures, particularly where the tissue is macerated or in the presence of extensive scarring from previous surgery.

11.2 Tendon Surgery

- **Tendon rupture –** The risk of rupture following primary flexor tendon repair is approximately 3–9% [2] and can be due to patient factors (such as misuse of hand, smoking) or surgical factors (such as poor repair technique, delay in repair, zone of injury). This will likely necessitate urgent assessment and a return to theatre for secondary repair which can often be staged and require extensive post-operative hand therapy. The importance of post-operative hand therapy rehabilitation cannot be underestimated, and smoking cessation advice strongly given. Early active mobilisation has been associated with stronger repairs and reduced adhesion formation.
- **Adhesions –** Adhesions occur in approximately 20% of cases [3]. The formation of adhesions post tendon repair appears to be multi-factorial and linked to the degree of trauma to the synovial sheath, amount of intra-operative tendon handling, and the timing of post-operative mobilisation [4]. If adhesions develop which limit function, the patient may be require tenolysis 3–6 months following the original tendon repair [5].

11.3 Nerve Repairs

- **Neuroma –** These are painful bundles arising from disorganised axonal growth which can form an extremely painful nidus in the digit. Primary nerve repair is primarily done to minimise the risk of neuroma formation, but the patient must be prepared for the fact that it may still occur. If so, this can be excised at a later date. Patients should also be counselled on the fact that return of sensation may not occur despite surgical nerve repair, particularly in elderly patients and smokers.
- **Cold intolerance –** Cold intolerance is a response to cold temperatures resulting in pain, paraesthesia, weakness and/or colour changes [6]. It has been reported to occur in

over 30% of patients with upper limb injuries and is most commonly triggered by exposure to cold air. All patients should be informed of cold intolerance, in particular those consenting for digital nerve repair, fingertip injuries and digital replantation.

11.4 Fracture

- **Non-union/delayed union/mal-union –** Non-union is when a fracture demonstrates no signs of unification between the fracture fragments, despite an adequate amount of time elapsing for fracture union to occur. This may be due to infection or open fractures and often quire operative management [7]. Delayed union refers to a slowly healing fracture which has an increased propensity to be deformed over time. Surgical intervention is rarely needed. Mal-union often occurs following non-operative management of fractures or poor bony fixation technique when surgical management is chosen. Angular or rotational deformity correction may necessitate re-operation, which is often challenging.
- **Complex regional pain syndrome (CRPS) –** It is a poorly understood condition, which can be precipitated by the initial trauma or the surgery and is three times more common in women. The pain severity may be out of proportion to the injury and be described as "burning" or "aching" and may be associated with changes in skin colour and moisture. CRPS may occur following any form of hand trauma, but occurs most commonly following bony fracture [8]. Early diagnosis, oral analgesia and physiotherapy are the mainstay of management.
- **Further fracture** – Further fractures may occur during manipulation of bony injuries and peri-new prosthetic fractures may arise when at the time of implantation of metalwork during fracture fixation.
- **Metalwork removal** – The use of metalwork in fracture fixation may predispose to the formation of overlying tendon adhesions and scarring, causing discomfort, protrusion

through the skin or reduced hand function. This may necessitate secondary surgery to remove the metalwork. Patients should be informed of the possibility of planned removal of metalwork in the future, which may be performed under local anaesthesia or general anaesthesia particularly in paediatric patients.

11.5 Nail Bed Repair

- **Abnormal/absent nail growth** – The most important reason for repairing the nailbed is to reduce the likelihood of an underlying open fracture infection. It is important to clarify with the patient that despite surgical repair of the nail bed, some deformity may persist due to scar tissue on the repaired nailbed. Surgical intervention may reduce the risk of an irregular nail contour, but does not completely eliminate the possibility. Nail deformities occur particularly in cases of trauma to the germinal matrix. It normally takes 3–6 months for the new nail to grow.

11.6 Consent Forms

Various consent forms exist and the correct one must be used for the correct situation;

- Consent form 1: Where the adult patient with full mental capacity agrees to a procedure.
- Consent form 2: Where the parent or person of parental responsibility agrees to the procedure on behalf of a child, or for a child to consent to a procedure themselves.
- Consent form 3: Where a patient agrees to a procedure where their consciousness will not be impaired i.e. procedures under local or regional anaesthesia.
- Consent form 4: Where adults lack the capacity to consent for a procedure.

11.7 Consent for Medical Photography

Medical photographs are often taken as part of patient health records in order to accurately document physical appearance, and to guide future clinical decision-making. Photographers have a duty of care to protect patients' rights and dignity in taking clinical photographs. Indications for medical illustration may be extended to their use in teaching health care professionals, educating other patients or for formal publication in scientific journals or textbooks in the future. This requires clear explanation to the patient and explicit written consent from the patient. Photographs and videos should be taken using approved equipment in accordance with Trust policy and stored securely.

Take Home Messages

1. Informed consent is a legal requirement prior to surgical intervention
2. Patients should be informed of both general and specific risks and complications, with particular relevance to their current clinical, social and psychological status
3. The possibility of further surgery, where applicable, should be clearly explained to patients
4. Written consent for medical photography should be performed when possible

References

1. Royal College of Surgeons of England Professional and Clinical Standards – Consent: Supported Decision Making. A guide to good practice. London: Royal College of Surgeons of England; 2016.
2. Elliot D, Moiemen NS, Flemming AF, Harris SB, Foster AJ. The rupture rate of acute flexor tendon repairs mobilized by the controlled active motion regimen. J Hand Surg Br. 1994;19:607–12.
3. Manske PR. Flexor tendon healing. J Hand Surg Br. 1988;13:237–45.

4. Strickland JW, Glogovac SV. Digital function following flexor tendon repair in Zone II: a comparison of immobilization and controlled passive motion techniques. J Hand Surg Am. 1980;5A:537–43.
5. Strickland JW. Results of flexor tendon surgery in zone II. Hand Clin. 1985;1:167–79.
6. Novak CB, McCabe SJ. Prevalence of cold sensitivity in patients with hand pathology. Hand (New York NY). 2015;10(2):173–6.
7. Hammert WC. Treatment of nonunion and malunion following hand fractures. Clin Plast Surg. 2011;38(4):683–95.
8. Li Z, Smith BP, Tuohy C, Smith TL, Andrew Koman L. Complex regional pain syndrome after hand surgery. Hand Clin. 2010;26(2):281–9.

Chapter 12
Referrals from Primary Care

Rakesh Singh

Hand trauma injuries or infections either present first to A&E or to Primary Care. The General Practitioner (GP) must therefore be aware of how to manage immediate first aid, and how to triage patients between those who must be seen urgently, those who can wait for the next available trauma clinic, and those who can be referred to an elective clinic. Furthermore, clinicians in the fields of plastic and orthopaedic surgery must also be familiar with referral guidelines to streamline this process, offer appropriate advice, and ensure patients are seen with suitable urgency.

When seeing patients in Primary Care, it is imperative that a thorough history and examination are done, and first aid is started to ensure a smooth and efficient handover of information to the plastic surgery team. It is also important to be aware of the services offered by the local plastic surgery centre. For example, burns can be escalated from a burns facility, to a burns unit and finally a burns centre, depending on the severity of the injury and the need for specialised treatment.

R. Singh (✉)
General Practitioner, All Saints Surgery, Burton, UK
e-mail: Lily.singh@nhs.net

P. Singh (ed.), *Hand Trauma in Clinical Practice*, In Clinical Practice, https://doi.org/10.1007/978-3-030-10844-1_12

12.1 Injuries Needing Urgent Plastic Surgery Referral

Many injuries will be in the context of high energy trauma and all other injuries should be explored. A full ATLS algorithm approach may be required. More detailed assessment of these injuries can be found in earlier chapters.

Amputation Care must be taken to wash the proximal stump where possible and apply sterile, non-adherent dressings. The amputated tissue should be wrapped in sterile, saline soaked gauze, placed inside a plastic bag which is itself placed inside another plastic bag containing ice and water. Tetanus, oral antibiotics and a high arm sling should be provided.

Avulsion injuries Wherever possible, the distal perfusion of the digit should be checked, then management is as for amputations.

Degloving injuries Perfusion of degloved tissue should be checked. The extent of degloving and which underlying structures are exposed will determine the urgency of referral. Where there are exposed tendons or bone, urgent referral should be made. If there is loss of skin and soft tissue on particularly functional or aesthetic parts of the body, urgent referral should be made as a formal debridement, assessment of neurovascular status and subsequent skin grafting or flap reconstruction may be required.

Burns The patient should be addressed holistically with a history of agent involved in causing the burn, duration, time since burn, location of injury, whether there was a flame involved in a closed or open space, and what treatment has already been administered. The patient should be examined

for inhalation injuries and cognitively for potential carbon monoxide poisoning, the %TBSA injured, an estimation of depth, and where the burns are.

Furthermore, burns can be socially and psychologically damaging, and a good relationship with the GP will pay dividends to patient outcomes. Additional referrals to support groups and counselling may also be required in the longer term.

The National Network for Burn care have issued guidelines entitled 'National Burn Care Referral Guidance' on which injuries should be referred to higher levels of burn service [1]. They stipulate that referral to a specialised burns service should be made in;

- All burns ≥2% TBSA in children or ≥3% in adults
- All full thickness burns
- All circumferential burns
- Any burn that has not healed within 2 weeks
- Any suspicion of NAI
- All burns to hands, feet, face, genitalia
- All burns caused by electricity, chemical agent, friction or cold
- Any child who is unwell + has a burn
- Any patient who you are concerned about, particularly those with comorbidities

Crush injuries These may be associated with open fractures, significant soft tissue loss, vascular compromise, and potentially compartment syndrome with its sequelae. One should examine for perfusion status, extent of soft tissue loss, and compartment syndrome in the upper limb.

High pressure injection injuries These are often seen in manual labourers with paint or sand guns. The extent of injury cannot often be assessed until exploration in theatre. There is a high risk of compartment syndrome which must be examined for.

Hand infections The area, depth, extent of functional limitation and systemic health of the patient should be factors in deciding how aggressively to treat infections. Injuries contaminated by bites, murine, agricultural or sewage waste must be washed and referred immediately. Superficial infections may be treated with a course of oral antibiotics and close follow up, with the patient educated about red flag signs and symptoms and a safety net in place. Collections require incision and drainage (I&D), such as paronychias or felons, which may be carried out in a GP setting with adequate training. Deeper collections should be referred for I&D in theatre.

12.2 Injuries Needing Referral to Plastic Surgery Trauma Clinic

Closed fractures In most cases, analgesia and splintage are required in the immediate setting. If the fracture is significantly displaced, or there is vascular compromise, then a fracture reduction should be attempted, and more urgent referral made to the plastic surgery team.

Closed joint dislocations These should be treated similarly to closed fractures, but they should be reduced wherever possible and ligamentous injury examined for. Hyperextension injuries including volar plate injuries are included here.

Lacerations The extent, depth and location of injury determines escalation. Superficial lacerations may be treated in the community with dressings or sutures. Deeper lacerations, and those involving glass should raise suspicion of damage to deeper structures which may warrant a formal EUA and repair of structures. As long as the digit is perfused, these injuries can be referred to the next plastic surgery trauma

clinic. This includes concerns over nerve or tendon injuries. In the immediate setting, a thorough washout, dressing, tetanus and antibiotics should be given if required.

Foreign bodies Small foreign bodies will usually work their way out in time. However, where they are painful, causing infection, or potentially penetrating underlying structures such as the flexor sheath or joint capsules, they should be referred for consideration of removal.

12.3 Injuries Requiring Referral to Plastic Surgery Elective Clinic

Old fractures After 3 weeks, there has often been sufficient bone healing that the fracture is difficult to manipulate and often osteotomy is required. This should be done by a consultant hand surgeon.

Old tendon injuries After 2–3 weeks, flexor tendons in particular have retracted further up the arm. The muscle belly is also likely to have reduced. This often means primary tendon repair is not possible and a staged approach with extensive hand physiotherapy rehabilitation will be required. Patients should be referred to consultant hand surgeons to discuss this option and understand the lengthy journey ahead. Alternatively, arthrodesis can be carried out and the specialist can discuss the pros and cons with the patient,

Dupuytrens contracture This is a progressive disease affecting the volar aspects of the hands, causing fibrotic contractures that require percutaneous or open release. It is multifactorial in aetiology and can be improved with surgery and hand physiotherapy.

Trigger finger/stenosing tenosynovitis Believed to be caused by trauma to the flexor tendons causing inflammation which reduces glide as the tendon gets stuck under the A1 pulley and must be passively extended. In time a nodule may develop on the flexor tendon. This can be treated with physiotherapy and splinting, corticosteroid injections or tenolysis.

Glomus tumours These are neoplasms arising from the glomus body causing a nodule which is excruciatingly painful. This can be debilitating for the patient's hand function. It is treated with excision. One must be aware of amelanocytic melanoma presenting in a similar way so all excised lesions should be sent for histopathology.

Pyogenic granulomas These are benign overgrowths of granulation tissue often arising after injury to the hand. They can be a nuisance as they catch easily and bleed freely. They can be treated by topical application of steroids, imiquimod, or silver nitrate, frozen using liquid nitrogen, or excised and cauterised.

Carpal tunnel syndrome This is caused by increased pressure within the carpal tunnel. There are numerous aetiologies which can be managed in the community. Weight loss, occupational changes, hand therapy and splints can be effective, otherwise surgical carpal tunnel release can be performed.

Congenital disorders There are a spectrum of congenital hand abnormalities from syndactyly to symbrachydactyly. Early referral to a hand consultant is warranted so they can plan surgery at appropriate ages for the patient.

Reference

1. https://www.britishburnassociation.org/wp-content/uploads/2018/02/National-Burn-Care-Referral-Guidance-2012.pdf.

Index

P. Singh (ed.), *Hand Trauma in Clinical Practice*, In Clinical Practice, https://doi.org/10.1007/978-3-030-10844-1

V

W